UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 327

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER February 19, 1916

THE SPRUCE AND BALSAM FIR TREES OF THE ROCKY MOUNTAIN REGION.

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SCOPE OF THE BULLETIN.

This bulletin deals with the distinguishing characters, geographic distribution, and forest habits of all of the spruce and balsam-fir trees that grow naturally within the Rocky Mountain region, which roughly includes the desert and mountain territory lying between the Great Plains and the eastern border of the Pacific Slope States. Canadian territory lying directly north of our Rockies and Mexican territory adjacent to our Southwest are included, because the ranges of some of the spruces and firs extend into these regions. The method of treating the subject, sources from which data on the geographic range were obtained, and the origin of other information used in this bulletin are fully discussed by the writer in a recently issued publication on the "Cypress and Juniper Trees of the Rocky Mountain Region."[1] Acknowledgments made there of assistance received apply also in the case of the present bulletin.

[1] Bulletin No. 207, U. S. Department of Agriculture, 1915.

NOTE.—This bulletin will be of service botanically or commercially for the trees described.

The class and family relationship of the spruces and balsam firs to other cone-bearing trees of the Rocky Mountain region is fully explained in the above-mentioned publication, to which the reader is referred for this general information.

Keys are provided on pp. 42 and 43 for the identification of genera and species.

GENERIC CHARACTERISTICS OF SPRUCES.[1]

The spruces are evergreen trees with sharp-pointed, pyramid-shaped crowns and conspicuously straight, tapering trunks. The branches grow from the trunks in regularly distant circles or whorls. Their stiff, acute, often very keenly pointed, single leaves have a characteristic spiral arrangement on the twigs and branches which they clothe on all sides. The leaves of each season's growth adhere to the branches for from about 7 to 10 years. When the leaves die and fall from the branches they leave a basal portion which gives the branches a rough appearance.[2] All but two of the North American spruces have more or less distinctly 4-angled leaves, all sides of which are provided with minute stomata or pores. Leaves of the other two species are flat, being very indistinctly 4-angled, or flat triangular in cross section, and with minute pores only on the upper surface. In cross section the leaves of spruces usually show one or two resin ducts situated very near the lower surface; in some cases the leaves have no resin ducts. The winter buds of the spruces are made up of overlapping scales and, unlike those of the fir trees, have no resinous covering.

Male and female flowers of spruces are borne on the same tree and on twigs of the previous year's growth. The male or pollen-bearing flowers are upright or drooping, yellow, bright purple, or rose-red, long or short, cylindrical bodies, about three-fourths inch to 1 inch by one-fourth to one-half inch. The female flowers, which produce cones and seed, are erect, yellowish-green or bright

[1] Considerable confusion still exists, especially among nurserymen, regarding the trees that are properly included in the genus Picea, which in 1830 the German botanist Link technically adopted as a generic name for the true spruces as we now know them. It seems probable, but this can not be established, that Pliny first used Picea as a classical name for a fir and Abies for a spruce tree. Later writers used Picea for the spruces and Abies for the firs, while in 1719 Tournefort consigned the firs, spruces, and our hemlock to the genus Abies. In 1754 Linnæus went still farther by combining under Pinus the firs, spruces, hemlock, and larch. This gave rise to such peculiarly anomalous technical names as "Pinus abies" for the Norway spruce, "Pinus picea" for the European silver fir, and "Pinus larix" for the European larch. As late even as 1836 Endlicher maintained Link's use of Picea for the spruces, but made it a subgenus of Pinus. From 1837 to 1858, however, such eminent authors as D. Don, Loudon, and Gordon used Abies for the spruces and Picea for the balsam firs. Notwithstanding the fact that properly all European and American botanists maintain Picea as the only legitimate generic name for the spruces and Abies for the firs, many European and American nurserymen and horticulturists continue to use Picea for the firs and Abies for the spruces, some even including the hemlocks (Tsuga) in the latter genus.

[2] See p. 18 for statement regarding the characteristic leaf-scars of firs.

red bodies of similar form, from three-fourths inch to about 1¼ inches in length by one-fourth to nearly three-fourths inch in diameter. The cones, matured in one season, are cylindrical or egg-shaped, always pendant or bent downward (Pls. I to V). Most of the spruces bear their cones at the extreme top of the crown; some bear cones on branches of the upper half of the crown. As a rule, the cones are only lightly attached to the twigs, and after shedding their seed, in early or late autumn, they either fall from the trees during the winter or by spring. The cones of a few spruces are firmly attached and remain on the branches for a number of years after their seeds are shed. The scales of spruce cones are thin and without prickles (Pls. I to V), in this respect being unlike the thick, strong cone scales of pines, which often have sharp, strong prickles. Like the cone scales of the pines, however, they are firmly attached to a central woody column, and never fall away until the cone is rotted to pieces. Two seeds (Pl. I, *b*) are borne under each fertile cone scale; no seeds are produced by the usually much-aborted scales at the two ends of the cones. The seeds are light and provided at one end with a thin wing which renders them so buoyant that the wind disseminates them widely. The seed-leaves, the first foliar organs to appear after the seed germinates, are commonly from 5 to about 15, or sometimes only 4 in number (Pl. III, *b*).

The spruces are exceedingly important forest trees, and some are much planted for ornament. They yield superior saw timber, the straight and even grained wood being used for a great many commercial purposes, including paper pulp, for which it is unsurpassed.

Seven species are indigenous to North America, all of which occur abundantly, or exclusively, within the United States. Four species are distributed over the western half of the United States, and three range mainly through northeastern United States and Canada, while two of these extend, almost entirely in Canada, from the Great Lake region into Alaska.

Species of this genus are of ancient origin, representatives of the group having existed from the Middle Cretaceous period to the Recent, while cones of both Picea canadensis and P. mariana, the white spruce and black spruce of to-day, are abundant in postglacial deposits at Chicago, Ill.[1]

BLACK SPRUCE.

Picea mariana (Mill.) B., S., and P.

COMMON NAME AND EARLY HISTORY.

This species has long been known as black spruce, a name probably joined from the tree's most widely used technical name, Picea nigra,

[1] The writer is indebted for this statement of the geologic history of Picea to Dr. Edward W. Berry, paleontologist, Johns Hopkins University, Baltimore, Md.

doubtless suggested by the dark blue-green foliage, which contrasts strongly with the ashy or glaucous green hue of the white spruce found in the same general region. "Swamp spruce," "bog spruce," and "muskeg spruce," are local names applied to it when found growing in wet, marshy places. Black spruce was doubtless well known to the French and English settlers in eastern Canada and New England at least as early as the seventeenth century, but the first definite account of it was not published until 1755,[1] and then not under a technical name. The black spruce was first technically described and named "Abies mariana Miller" in 1768. From 1800 to 1888 it was, however, known to botanists and horticulturists as Abies nigra and as Picea nigra, its present accepted name, Picea mariana (based on A. mariana), not being established until 1888.

Several different forms of the black spruce have been named as distinct species (now doubtfully tenable), while about seven named horticultural varieties are distinguished in cultivation.[2]

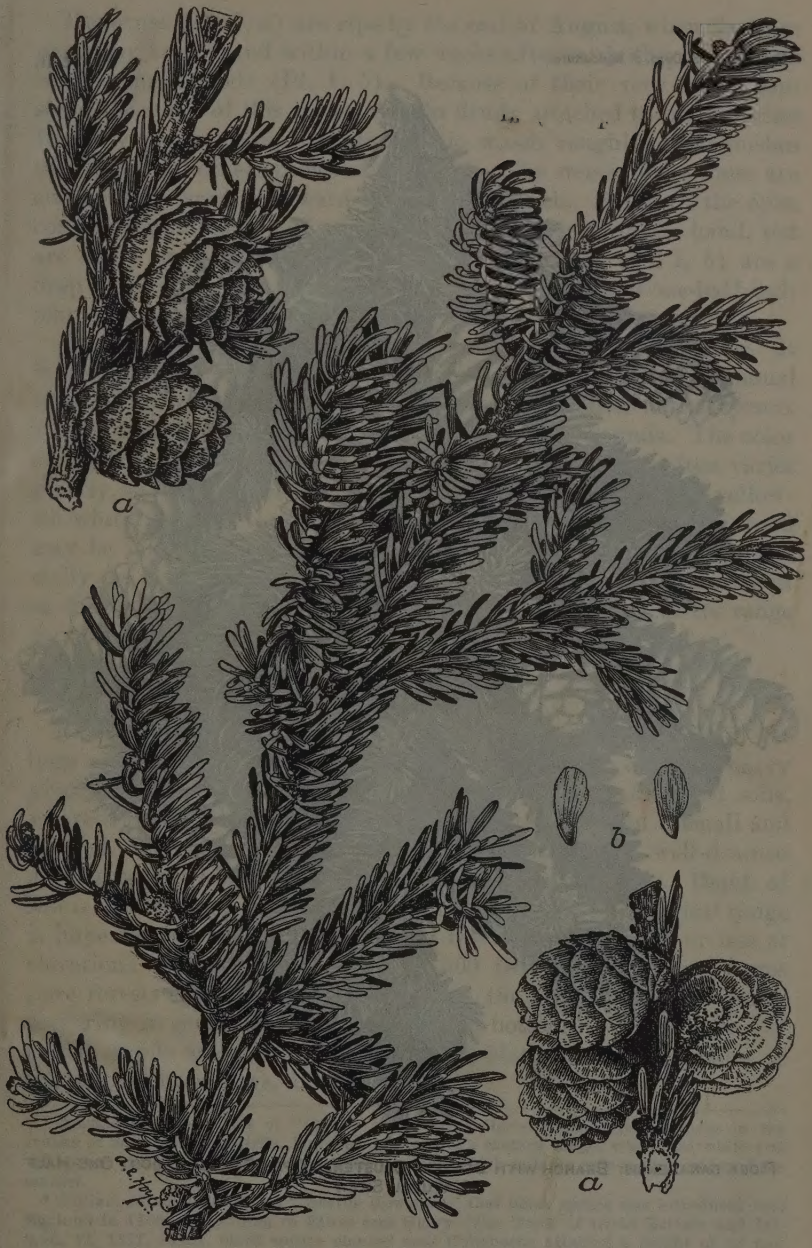
DISTINGUISHING CHARACTERISTICS.

Black spruce is mainly an eastern and far northern species, included here because it occurs in the Canadian Rocky Mountain region. There it is from 25 to 40 feet high and from 4 to 8 inches in diameter. In its wider eastern range this tree exceptionally attains a height of from 50 to 75 feet and a diameter of about 1 foot; very occasionally it grows to 100 feet in height and 2 to 3 feet in diameter. The crown is characteristically open and irregular, extending to the ground, except in middle-aged or old trees grown in a dense stand, where the lower half of the trunk is clear of branches. The usually short, slim branches, often distant from each other, commonly droop at their ends, but some forms of the tree have peculiarly stiff branches. A stunted form of this tree growing in wet marshes has tufts of very short branches, only or chiefly, at the top of the stem. The great variation in the habit of the branches and density of the crown appears to be due entirely to differences in habitat, which ranges from wet, boggy marshes to dry uplands.

The foliage is a deep blue-green, with a tinge of whitish, the short leaves (Pl. I) standing out on all sides of the branches. A cross section of the leaves shows two minute resin ducts close to the surface and near the angles of the leaf. The bark of old trees is thin and composed of small ashy-brown scales. The young twigs of a season's growth are usually a pale russet-brown, coated with small hairs of similar color.

[1] Du Hamel, Traité des arbres et arbustes, I, 17, 1755.

[2] See Nomenclature of Arborescent Flora of U. S. (Bull. 14, Div. Forestry, U. S. Dept. Agr.), 34, 1897. These "varieties" are distinguished chiefly by slight differences in the shape of the crowns and by the color of the foliage. The variety known in cultivation as "Picea nigra Doumetii" is very distinct in its narrowly pyramidal, dense crown.



PICEA MARIANA: FOLIAGE.

a, Open cones; *b*, upper (left) and lower sides of seeds with wings.

PICEA CANADENSIS: BRANCH WITH DENSELY CLUSTERED OPEN CONES. (ABOUT ONE-HALF NATURAL SIZE.)

The cones (Pl. I, *a*) are ripe by the end of August, when they are pale ashy brown, and within a few weeks afterwards they shed their small winged seeds (Pl. I, *b*). Because of their very stout, firm stems the cones of this spruce remain firmly attached to the branches for very many years, a characteristic which roughly distinguishes this tree from other species of its range. The stems of the cones are curved downward or inward toward the branch. Scales of the open cones are peculiarly stiff and resistant to pressure of the hand, but are easily broken if squeezed together. The seeds (Pl. I, *b*) are a deep chocolate brown. Seed-leaves, usually 6, are about one-half inch long or shorter.

Black spruce wood is usually of a clear, very light yellow color. It is characterized by a thin layer of sapwood and very narrow annual rings of growth. It is heavier than that of any other native spruce, a cubic foot of seasoned wood weighing nearly 33 pounds. The color of wood from different individual trees of this species often varies greatly, so that it is easy to confuse the wood with the pale or yellowish-white wood of the white spruce, with which black spruce wood may be mingled occasionally as lumber. Black spruce is commercially the least important of all the eastern spruces, chiefly on account of the small size of the tree, which in the eastern part of its range is cut mainly for paper pulp.[1]

OCCURRENCE[2] AND HABITS.

Black spruce is essentially a swamp tree, characteristic of cold, wet bogs and margins of lakes (Map No. 1). It grows on clay and heavy glacial drift, and occasionally also on high, well-drained hill soils, where it is much less abundant than in moister sites and is small and stunted. The best growth is found in constantly moist, well-drained alluvial soils, while the tree is most abundant in wet soils. Depth of soil is not essential, owing to shallow root system. The vertical range is imperfectly known at present, but the tree occurs more or less at elevations between about 100 and 3,500 feet. Black spruce forms pure forests over limited or small areas, the largest and best stands occurring in moist, well-drained alluvial bottoms. It also grows in mixed stands associated with tamarack, black cottonwood, balm of Gilead, aspen, willows, and alders.

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[1] Considerable quantities of "spruce gum" are collected from injured places in the trunks of black spruce, chiefly, however, in the tree's eastern range, where the white and red spruce also yield a part of this crude product, which is later refined and prepared for market.

[2] William Aiton states in his "Hortus Kewensis" that black spruce was introduced into England in 1700. According to Elwes and Henry (The Trees of Great Britain and Ireland, VI, 1377, 1912), black spruce planted near Colesborne attained a height of 56 feet and a diameter of about 11 inches in 55 years. Trees planted in Scotland in 1832 were 40 feet high in 1904. The trees planted in moist or wet situations appear to be thrifty, while those set in drier places have proved to be short-lived.

It is very tolerant of shade, being able to recover from suppression up to an advanced age. Dense stands of black spruce produce a heavy crown cover, which frequently shades out tamarack and other intolerant trees. Black spruce is most tolerant on wet soils, which are often covered with dense stands of slow-growing trees, and least tolerant of shade in dry, well-drained situations, where it usually grows in more open stands. Ability to endure dense shade enables the trees to retain their side branches for a relatively long time, those with clear trunks occurring only in the densest stands.

Black spruce is not a prolific seeder, although some seed is usually borne locally each year; abundant seed production occurs only at rather long, irregular intervals. The seed has a moderately high germination and persistent vitality. Germination is best on constantly moist mineral or humus soils, on wet, decayed fallen trees, moss, and moist, decomposed spruce leaf litter. The leaf litter of broadleaf trees is not, as a rule, favorable to germination, because the seedling roots can not penetrate the tough mass of duff. Seedlings require at least moderate shade for their development during the first one or two seasons, while the young plants grow most thriftily in dense shade.

The lower branches of black spruce trees frequently take root when lying in close contact with moist earth or leaf mould, and produce clusters of little trees under the shade of the mother tree.

LONGEVITY.

In general, black spruce is moderately long-lived, trees of average size being from 125 to 200 years old. Trees in wet situations grow very slowly, often only 1 to 2 inches in diameter in 75 or nearly 100 years. Further age determinations are desirable of trees grown in the moister and drier situations.

WHITE SPRUCE.

Picea canadensis (Mill.) B., S., and P.

COMMON NAME AND EARLY HISTORY.

Picea canadensis is most commonly and widely known as white spruce, this name referring to the whitish hue of the foliage. It is also locally known as "cat spruce" and "skunk spruce" because of the polecatlike odor given off by the foliage and young twigs, especially when crushed. White spruce was the first of our spruces to receive published notice, an account of it appearing as early as 1535[1] and again in 1620.[2] The first of these records refers to trees

[1] "Bref Recit et Succincte Narration de la Navigation faite in mdxxxv. mdxxxvi, Parle Capt. Jacques Cartier aus Iles de Canada," 24, 1535.

[2] John Mason, "A Brief Discourse of the Newfoundland."

seen along the Saguenay River, in southeastern Quebec, Canada, and the second account tells of trees observed in Newfoundland, where the species is abundant. It was technically described and named for the first time as "Abies canadensis Miller" in 1768, although the author of this name previously described the tree without naming it in 1731. During the century and a half that white spruce has been known to science no less than 20 different specific and varietal names have been given to various forms of it.[1] Down to 1888 botanists knew it chiefly either as "Abies alba Michaux" (published in 1803) and as "Picea alba Link" (published in 1831), its present generally accepted name, Picea canadensis (based on Abies canadensis Mill.), having been established in 1888.

DISTINGUISHING CHARACTERISTICS.

White spruce is only sparingly represented in our Rocky Mountain region, its main range being in northeastern United States and Canada. It varies in height, according to situation, from 15 to 75 feet and in diameter from 12 to 20 inches. The largest trees occur in the East, where the height is from 80 to 100 feet or more and the diameter from 24 to 36 inches. Trees 3 or 4 feet in diameter and over 100 feet high are rather rare. The trunk is straight and clear of branches for one-third to two-thirds of its length, with a somewhat open, irregular, and widely pyramidal crown, the top of which, especially in old trees, may be rounded or flattened; very often, however, the crown is sharply pointed. The branches are long and thick, and commonly curve down and then upward. A striking characteristic of the branches is their numerous small, drooping side branchlets.

Bark of the trunks is thin, rarely over one-half an inch thick, and is early broken into small, thin, pale, ashy-brown scales, the color, however, varying greatly with the density of the stand.

The dense foliage is characteristic in its light blue-green color, which in some individuals has a distinct whitish tinge.[1] The 4-angled leaves (Pl. II) grow from all sides of the twigs, and often stand out loosely; but for the most part they appear to grow on the upper sides of the branches, particularly at and near their ends, the lower leaves being bent upward, so that all appear to be massed on the upper side. A cross section of the leaves shows two minute resin ducts close to the border and near the angles of the leaves. Twigs of a season's growth are dark yellow-brown, and, as a rule, are

[1] White spruce has been cultivated for ornament for many years both in Europe and in this country. Loudon (Arb. et Frut., IV, 2312, 1838) informs us that Bishop Compton introduced it into England in 1700. Some 10 different garden forms have been developed and are now technically named. They are all distinguished from the species chiefly by their smaller size, shape of the crown, or color and habit of foliage and branches. The best marked garden variety is P. canadensis glauca, which is a handsome form with pale blue-green foliage closely pressed upon the twigs.

smooth, but twigs of the far northwestern forms of this species are apt to be finely downy. A notable distinguishing character of the foliage and young twigs is the fetid, polecatlike odor they emit, especially when bruised. Foliage a year old or older gives off a much less distinct odor, while the odor of foliage from different trees varies greatly in intensity.

The pendulous cones (Pls. II and III) are borne mostly at the top of the tree, but occasionally a few are produced on the middle and lower crown branches. They reach maturity by the end of one summer, when they may be light grass-green tinged with red or bright rose-red. The small, light, yellow-brown seeds (Pl. III, *a*) are shed in September. After shedding their seeds the cones are a light clay-brown. Being lightly attached to the twigs, they usually fall from the trees during autumn or by the following spring. They vary in length from about 1 inch to nearly 2½ inches, but are usually about 1¾ inches long. When open and dry the cone-scales are so thin and flexible that they can be squeezed together without breaking them. The seed-leaves (Pl. III, *b*), which vary in number from 6 to 9, are slender and from one-half to nearly three-fourths of an inch long.

The wood of white spruce is pale yellowish-white, rather soft in texture, straight-grained, and with very narrow growth rings; the thin layer of sapwood is only slightly paler than the heartwood. White spruce wood ranks fourth in weight among native spruces, a cubic foot of seasoned wood weighing 25¼ pounds. Commercially the white spruce is one of the two most important timber spruces of northeastern North America.[1] Here it is extensively cut for lumber, which is used in general construction work and for interior finish. Large quantities are also cut for paper pulp. In its western range white spruce is locally used chiefly for lumber in rough construction work.

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[1] Stewardson Brown believes there is a second distinct species of white spruce which he found in the Canadian Rockies of Alberta and British Columbia. He describes this tree as growing at low altitudes in wet ground and on river bottoms, where it often occurs to the exclusion of all other trees. Dr. N. L. Britton ("North American Trees," p. 58, 1908) has given this species the common name "Western white spruce" and states that it ranges "from Wyoming and Montana north and westward into British Columbia." Mr. Brown's description of the tree follows:

"This species has been referred by authors to Picea canadensis (Mill.), B. S. P., and P. mariana (Mill.), B. S. P., to both of which it bears a certain resemblance, but from two months' experience with the tree during the past season in the region from Banff, Alberta, to Field, British Columbia, I am satisfied that it is quite distinct from either, and therefore propose for it the following name:

"Picea albertiana sp. nov.—A slender tree, attaining a height of over 15 meters. Twigs and sterigmata smooth and shining or occasionally slightly granular but never glaucous, yellowish brown when young, becoming darker with age; sterigmata strongly reflexed and standing out frequently more than 1 millimeter from the twigs; leaves pale blue or blue green, surrounding the stem and crowded toward the upper side, at the ends of the branches, 1.5 to 2.5 centimeters long, four-sided, with three, four, or sometimes five rows of stomata on each side, incurved, acute, or acuminate with a rigid tip; cones

PICEA CANADENSIS: FOLIAGE AND OPEN CONES.

a, Upper (right) and lower sides of seeds with wings; *b*, seedling, one month old.

OCCURRENCE AND HABITS.

Picea canadensis occurs on river banks, terraces, dryish margins of swamps and lakes, and on adjacent sides of ridges and hills at elevations of from near sea-level up to about 5,000 feet (Map No. 2). It is most frequent on sandy loam soils with moderate moisture, but grows on very shallow soils from the margins of swamps to the tops of mountains. The largest trees are found in moist, well-drained, finely divided porous soil; situations too dry or too wet produce dwarfed, stunted, slowly grown trees. White spruce forms pure dense forests, often of great extent. It occurs also in mixed stands. Usually it forms extensive pure forests in well-drained soils along rivers and on lower valley slopes. On wet or moist flats it often gives way to black spruce, tamarack, or cottonwoods, and on dry terraces to lodgepole pine. At timber line it is sometimes associated with alpine fir. Dense groves and strips of pure white spruce occur frequently, closely associated with birch, alder, aspen, willows, and black cottonwood.

Picea canadensis is tolerant of considerable shade from the seedling to pole stages of growth. Young trees are able to maintain themselves for many years under rather heavy crown cover and to recover from suppression when given top light, being surpassed in this respect only by the black and red spruces. With top light the trunks of young trees retain their lower side branches persistently, long, clear stems occurring only in very close stands of older growth. Thriving under light shade of poplars and birches, this spruce often replaces these trees after fire or lumbering.

White spruce is a moderately prolific seeder. Considerable seed is produced locally every year, while heavy seed production occurs over parts of its range at more or less regular intervals of from five to eight years. The seed has only a moderately high rate of germination, but persistent vitality. Good germination of the seed occurs

ovate, bright crimson when young, at maturity 2.5 to 3.5 centimeters long and nearly as broad when expanded, early deciduous; scales stiff and rigid, broadly rounded at the apex, entire, broader than long, cinnamon-brown with a chestnut edging and shading to darker chestnut toward the base; bract 2 millimeters or less long, 1 millimeter broad, with a sharply angular, more or less acute erose tip.

"Type: No. 796, S. Brown, Bankhead, Alberta.

"The common spruce of the lower altitudes through the Canadian Rockies in Alberta and British Columbia, differing from P. canadensis (Mill.), B. S. P., in the longer, strongly reflected sterigmata, shorter, broader, and darker-colored cones, with broadly rounded scales and minute sharply angled bracts and from P. mariana (Mill.), B. S. P., in the lighter-colored smooth twigs with longer sterigmata and light-blue or blue-green leaves, and cones with broader, entire scales with angular-tipped bracts." (Torreya, vol. 7, 125, 126, June, 1907.)

The present author has not seen authentic specimens of this tree on which the above description is based. As nearly as can be judged from descriptions of its characters it appears to be closely related to Picea canadensis, particularly in the color and form of the foliage and cones. Dr. Britton's figures (l. c. 45) of a cone shows some of the cone scales, however, to be decidedly different in form from those of Picea canadensis.

only on moist, decomposed organic, or mineral soils. Natural reproduction is usually abundant under mature spruce on damp moss over organic soil, and on moss-covered decayed logs and stumps. White spruce reproduces itself poorly on thick leaf-litter of broadleaf trees, because, as in the case of black spruce, the seedlings can not penetrate the tough mass.

LONGEVITY.

White spruce is a long-lived tree, reaching an age of from 250 to 300 years.

ENGELMANN SPRUCE.

Picea engelmanni Engelmann.[1]

COMMON NAME AND EARLY HISTORY.

Lumbermen and other woodsmen know this tree mostly as "spruce," while some call it "white spruce," probably because of its general resemblance to the true white spruce (*Picea canadensis*), with which they may have become acquainted in the East. It is, however, commonly known to foresters and botanists as Engelmann spruce, a name which it is hoped may be generally adopted both because of its distinctness and the fact also that it commemorates the name of one of the ablest students of western trees.

It seems probable that Lewis and Clark were the first discoverers of this species, while crossing the Bitter Root Mountains in 1805 on the Lolo Trail. Mention is made in their narrative[2] of a "spruce," which must have been the tree we now know as Picea engelmanni. To Dr. C. C. Parry belongs the credit of having first distinguished this tree, in 1862, from the black spruce (*Picea mariana*), for which earlier plant explorers of the Rockies had mistaken it. In that year Dr. Parry found Engelmann spruce on Pikes Peak, Colo., and in 1863 is said to have sent seeds of it to the Botanic Garden of Harvard University, where it was probably cultivated for the first time in this country.[3] The first technically established name[1] and description of

[1] Dr. George Engelmann did not name this tree in honor of himself, as might appear from the present form of its technical name. Dr. Parry (Trans. Acad. Sci., St. Louis, II, 122, 1863), recognizing that this tree had been erroneously referred by Engelmann to Abies nigra (another distinct species), called it Abies engelmanni, which proved to be a nomen nudum. Later Engelmann (loc. cit., 212) cited Parry's name, A. engelmanni, and in doing this formed a new name, Picea engelmanni, which he credited to Parry. As a matter of fact, Parry did not write Picea engelmanni; consequently Engelmann was the first publisher of the name Picea engelmanni, but certainly with no intention of naming this tree in honor of himself.

[2] Hist. of Expedition under Command of Lewis and Clark (ed. Coues), II, 590. Whether the discovery was made on the Montana or Idaho side of the Bitter Roots, which the Lolo Trail crosses, appears to be unknown.

[3] According to James Veitch & Sons (A Manual of Coniferae, p. 69, 1881) Engelmann spruce was introduced into England in 1864, where it appears to grow thriftily. Later it was introduced into Germany and extensively tested for its value in forest plantations.

Engelmann spruce was published in 1863, since which time writers on North American trees have generally agreed in maintaining the different wild forms of this tree as one species.

Three or four garden forms of this spruce have been designated as varieties.[1] They are distinguished by their crown habit, size, or the color and length of the leaves.

DISTINGUISHING CHARACTERISTICS.

In dense stands Engelmann spruce has a straight, clean, slightly tapering trunk with a close, very short, narrowly pyramidal crown of small branches; the upper-crown branches are exceedingly short and form a narrow spirelike point. Such trees are from 80 to 100 feet or more in height, and from 18 to 36 inches in diameter. Larger trees occur sometimes, but they are now rather rare. When growing singly or in an open stand, Engelmann spruce has a similarly shaped but longer crown, with drooping lower branches often extending down to the ground. The middle-crown branches are horizontal and the top branches strongly upright. Trees of this form are usually from 60 to 80 feet high, with very tapering trunks, and if exposed to heavy winds the lower branches are often long and stout. From all of the main branches hang numerous tassel-like side branchlets which give the tree a very compact appearance. At high altitudes, Engelmann spruce is often not more than from 2 to 4 feet high, when the spikelike stem bears only a few short, densely leaved branchlets, while enormously long branches grow from the base of the stunted trunk and spread over the ground. The trunk bark becomes scaly even on rather young trees. On older and larger trees it is thin, dark purplish-brown or russet-red, and outwardly composed of very loosely attached small scales.

The foliage of Engelmann spruce is a deep blue-green, that of some trees being decidedly silvery or whitish. This silvery or whitish tinge is very marked on young trees, but occasionally large and moderately old trees still retain it. The 4-angled leaves (Pl. IV, *c*) are rather soft to the touch, usually about an inch in length, but often longer, especially on young, vigorous trees. The leaves are spreading on young twigs and on those which do not bear cones, while on cone-bearing twigs (Pl. IV) they are commonly crowded and usually shorter; they are also often curved so as to appear to grow mainly on the upper side of the branchlet. The point of the leaf is, as a rule, characteristically short and flattish, the short types of leaves exhibiting this more strongly than the longer ones (Pl.

[1] Picea engelmanni griseifolia Sudw. (="*P. e. glauca*"), P. e. argyrophylla Sudw. (="*P. e. argentea*"), P. e. minutifolia Sudw. (="*P. e. microphylla* Hesse"), and P. e. fendleri Henry are the garden varieties found in cultivation.

IV, *c*).[1] A cross section of the leaf shows no resin ducts. A disagreeable odor[2] is emitted by young leaves and young shoots when crushed. The twigs are more or less minutely hairy and remain so for about 3 years.

The cones, which mature in a single season, are ripe by the middle or latter part of August. Most of them are borne near the top of the crown. By October the seed is usually all shed. Cones (Pl. IV) vary greatly in length from about 1 to nearly 3 inches, the usual length being about 1½ inches. The cone scales also are very variable in outline. They are commonly narrowed to squarish ends; sometimes, however, the ends of the scales are pointed, and occasionally rounded.[3] When mature, and shortly after shedding their seeds, the cones are somewhat shiny, and vary in color from light brown to dark cinnamon-brown. They fall from the trees during autumn or early winter. The small winged seeds (Pl. IV, *a*) are blackish-brown. The seed-leaves are usually 6 (Pl. IV, *b*).

The wood of Engelmann spruce has thin layers of growth, is soft, straight-grained, and of a very light yellowish to faintly reddish-brown color. The sapwood is comparatively thick and as a rule only a trifle lighter in color than the heartwood. The wood is lighter in weight than that of any other native spruce, a cubic foot of seasoned wood weighing about 21½ pounds. Engelmann spruce is cut extensively for lumber, which is used for general construction and to some extent locally for interior finish. The timber is also much used for temporary or light-traffic ties, telephone and telegraph poles, mine props, fuel, house logs, and corral poles.

OCCURRENCE AND HABITS.

This species is essentially a tree of high altitudes (Map No. 3). Demand for soil moisture limits its occurrence to high elevations or to land moist from springs, seepage, or overflow. The lower range of Engelmann spruce is confined to moist canyons or to protected north slopes, while on other exposures it finds sufficient soil moisture only at higher altitudes. Owing to lower temperatures and less intense light in the North, favorable moisture conditions occur there at lower elevations than in the South, hence, in general, the gradual lowering

[1] Occasionally trees have exceptionally flat leaves with distinctly slender, keen points, in the latter character closely resembling lower-branch leaves of Picea parryana. The presence, however, of minute hairs on the twigs serves to distinguish this form from the blue spruce, which has smooth twigs.

[2] The odor is somewhat like that described for white spruce, but very much less pronounced.

[3] Picea columbiana Lemmon (Gard. & For., X, 183, 1897) appears to be based upon the northern form of Picea engelmanni, in which the cone scales are often more or less rounded at their ends. This form of Engelmann spruce is the one occurring commonly in Montana, Idaho, and British Columbia. Cone scales of Engelmann spruce growing in the central and southern Rocky Mountain States generally have squarish ends.

PICEA ENGELMANNI: FOLIAGE AND OPEN CONES.

a, Upper (left) and lower (right) sides of seeds with wings; *b*, seedling one week old; *c*, detached leaves showing variation in length (two and one-half times larger than natural size).

of the tree's altitudinal range of from 8,500 to 12,000 feet in the South to 6,000 feet in the North, with increasing latitude. This variation, however, is not consistent throughout the tree's range, because local climatic factors often have a modifying influence. Trees of merchantable size occur at the middle and lower levels, while chiefly stunted growths are found at timber line. Engelmann spruce shows little preference regarding the character of soil if there is sufficient moisture. It grows fairly well on dry soils, but usually gives way on porous soils to lodgepole pine, Douglas fir, and to other trees requiring better drainage. It thrives on retentive, fine, loamy soils, but attains the largest size on deep, rich, moderately moist soils of gulches and high river valleys. A shallow root-system enables this species to maintain itself on thin soils of slopes and on the wet margins of rivers, lakes, and swamps.

Engelmann spruce forms extensive pure forests and occurs also in mixed stands. Pure stands are somewhat more frequent in the South than in the North, where it chiefly meets trees of similar silvical requirements but of less extended southern range. In mixed stands it is found most frequently with alpine fir, Douglas fir, and lodgepole pine; occasionally it is associated with bristle-cone pine, white fir, and limber pine.

Picea engelmanni is very tolerant of shade, especially in youth, in this respect surpassing most of its associates. It endures years of shading and makes good growth when released from suppression. Owing to its great tolerance of shade this spruce forms close stands of many ages, thus preserving good forest conditions.

Engelmann spruce is a prolific seeder over most of its range. Large crops of seed are produced locally at intervals of about three years. The seed has a high rate of germination and remarkably persistent vitality. Seed so stored as to preserve its moisture and to prevent molding may show a germination of from 30 to 50 per cent after being kept four or five years. Trees begin to produce seed from about the twenty-fifth year and continue bearing it to an advanced age. Seeds germinate best in moist mineral soil, seedlings being rarely found in humus. Notwithstanding prolific seed production, seedlings are not generally abundant. Reproduction appears to proceed rather slowly but persistenly, seedlings being most numerous in small protected openings in the forest. Low branches of isolated trees also favor germination and protect seedlings, through which groups of trees are built up, and these combine with other near-by groups finally to form continuous stands.

LONGEVITY.

Engelmann spruce is a very long-lived tree, even in the most unfavorable situations. Trees from 16 to 22 inches in diameter are

from 350 to 460 years old. Stunted trees from 3 to 5 inches in diameter grown on high wind-swept crests are from 150 to 200 years old. Extremely large trees occasionally found would doubtless prove to be from 500 to 600 years old.

BLUE SPRUCE—"COLORADO BLUE SPRUCE."

Picea parryana[1] (André) Gardeners' Chronicle.

COMMON NAME AND EARLY HISTORY.

Blue spruce is popularly one of the most widely known North American conifers, and chiefly because of the handsome pyramidal crown form of young trees and the exceptional silvery hue of its foliage, which the common name "blue spruce" aptly describes. Because much of the cultivated stock is raised from seed obtained from Colorado, the tree is frequently called Colorado blue spruce. It was discovered 53 years ago on Pikes Peak, Colo., by Dr. C. C. Parry,[2] whose name it now bears. In the same year (1862) blue spruce was described for the first time and named "Abies menziessii Engelmann." This name had to be abandoned because in 1833 Lindley had applied it to another tree. In 1863 it was named "Picea menziesii Engelmann," which likewise proved to have been preoccupied in 1855. The first tenable name attached to the blue spruce is "Abies menziesii parryana André," which was published in 1876, and on which the present accepted name of this tree, Picea parryana, is based. Blue spruce is, however, very commonly known to growers of ornamental trees as Picea pungens Engelmann, which was published in 1879.[3]

[1] The question of what authority should be attached to Picea parryana (André), which is based on Abies menziesii parryana André (1876), is somewhat perplexing. Recent authors write "Picea parryana Sargent," which is presumably based on Prof. Sargent's publication of this combination in Garden and Forest (X, 482) in 1897 or on his use of this name in the Silva (XII, 47) in 1898. However, the Index Kewensis (Fasciculus III, 520) established Picea parryana in 1894 by citing as a synonym of it Picea pungens Engelmann (published in 1879), giving "Hort. ex Parry" (in Gard. Chron., XX, 725, 1883) as the authority for Picea parryana. Incidentally, Dr. Parry is not responsible for this name, in so far as published evidence is concerned, as reference to the page cited in the Gardeners' Chronicle will show, but a nameless writer for the above English journal. "Picea parryana" was, therefore, clearly established first in 1883 by this anonymous publication in the Gardeners' Chronicle, and there would seem to be no good reason why Gardeners' Chronicle, the actual authority for Picea parryana, should be ignored. It is perhaps unfortunate that the name of a journal must be cited as authority for a technical name, but strict observance of the facts in this case seems to make it unavoidable.

[2] Sargent, Silva, XII, 48.

[3] The first trees cultivated in this country were probably raised from seed which Dr Parry sent to the Botanic Garden of Harvard University, Cambridge, Mass., in 1863. (Gard. Chron., XX, 725, 1883.) This and many other later trials of the tree in our Northeastern and Middle Eastern States have shown that blue spruce can be successfully grown in these regions. The fact, however, that the great beauty of crown and the brilliant color of the foliage are gradually lost as the trees grow older limits the lasting usefulness of this species for ornament.

Blue spruce was probably introduced into England in 1877 (Gard. Chron., VII, 48, 562, 1877), where it grows thriftily.

The German Government began testing blue spruce in the latter part of the eighties from seed collected in Colorado, and Dr. Schwappach (Zeitschr. Forst- und Jagdwesen, XXXIII, 211, 1901) states that this species is well adapted for forest planting in northern Germany.

DISTINGUISHING CHARACTERISTICS.

The popularity of this spruce for ornamental planting is due to the exceptionally bright silvery-blue foliage[3] of some young trees. The brilliant color of young trees is, however, gradually lost as they grow older, the foliage of trees even 25 to 35 years old sometimes being decidedly greenish and lacking in beauty. With age also the early distinctly pyramidal crown, with branches down to the ground, becomes thin and irregular in outline, due to the uneven growth of the branches, and later the lower limbs disappear, leaving from one-fourth to one-half of the trunk clear. The thick, strong branches grow in rather distant circles or whorls about the trunk, and with their many much-branched, stiff, upturned side branches form peculiarly wide, flat sprays, especially in the lower and middle parts of the crown. The trunk is strongly conical. Full-grown trees, which sometimes form, as do some other spruces, two or more separate trunks, are from 70 to 90 feet, or, in specially favorable situations, from 110 to about 130 feet in height. The diameter varies from about 16 to 48 inches, but is commonly from 16 to 24 inches.

The bark of mature trunks is from one-half inch to 1⅓ inches thick, rather deeply furrowed, and composed of small, thin, elongated scales which are externally weathered to a light ash-color, sometimes with a brownish tint, and a bright red-brown beneath. The similarly colored bark of young trees is much thinner, irregularly broken and roughened by thin scales. The smooth 1-year-old twigs are clear reddish yellow, later becoming grayish, while the large buds, about one-half inch long, are light chocolate brown.

The quadrangular dull gray-green, blue-green, or silvery-white leaves (Pls. V, *b*, and VI, *b*) are stiff and very keenly pointed. As a rule, the latter characters at once distinguish this tree from the frequently associated Engelmann spruce, the leaves of which are bluish, but rarely as stiff and as keenly pointed as those of the blue spruce. The leaves bristle from all sides of the twigs, and are from seven-eighths inch to 1¼ inches long on lower branches, particularly of young trees (Pl. V, *b*), and one-half to three-fourths of an inch long on upper cone-bearing branches (Pls. V and VI). A cross section of the leaf shows one resin duct in an angle of the leaf. The leaves of each year's growth remain on the branches for from 8 to 9 years.

The cones, which are produced mainly on the upper fourth or third of the crown, mature in one season, and are from 2½ to 4½

[3] Seedlings show great variation in the intensity of the blue color of their foliage, and ornamental tree growers have developed, mainly by selection, at least half a dozen named horticultural "varieties" of this tree, each of which is distinguished chiefly by differences in the color of the foliage, which varies from green to bluish and silvery white. These forms are, however, not fixed in nature and have no stable botanical standing. One of the most brightly colored of these garden forms is the so-called "Koster blue spruce" (*"Picea pungens* var. *glauca Kosteri"*) propagated extensively in Europe.

inches long (Pl. V, *a*), but usually about 3½ inches. They are ripe by the middle or end of August, the thin, tough scales spreading slightly and shedding their seeds during September. In color the cones are a very light yellow-brown and rather shiny. A few of the empty cones fall during the first winter, but the majority remain on the trees until late autumn of the second season. The small seeds (Pl. VI, *a*) are dull chestnut-brown and have pale yellow-brown wings. Seed-leaves of the blue spruce vary in number from 5 to 6 (Pl. V, *c*).

The sapwood and heartwood are often very similar in color. When distinguishable, the heartwood is pale brownish-yellow to light straw color, while the sapwood is nearly white, the smoothed surface of both having a silklike sheen. Seasoned wood is rather light, weighing about 23 pounds per cubic foot, ranking fifth in weight among our spruce woods. It is moderately soft, brittle, and with narrow, often exceedingly narrow, rings of growth. Owing to the limited supply and the commonly knotty character and otherwise inferior quality of the wood, it is the least valuable of all of our native species for commercial purposes. It is rarely used, except locally for house logs, corral poles and posts, temporary mine props, fuel, and occasionally for railroad ties.

OCCURRENCE AND HABITS.

Single trees, small groups, and scattered pure groves of limited size occur along the immediate banks of streams flowing in deep and shallow canyons, and in broad, open, grassy valleys. (Map No. 4.) Occasionally single trees are found several hundred yards away from streams and 200 to 300 feet above the water. The largest trees are always found near water. Blue spruce grows in moderately rich dry to moist gravelly, sandy, or rocky soils, at elevations between about 6,000 and 8,500 feet, sometimes ascending to nearly 10,000 feet. It is associated mainly with Engelmann spruce, alpine fir, and occasionally with narrow-leaf cottonwood.

The light requirements of blue spruce are imperfectly known at present, but it is closely similar in tolerance of shade to the Sitka spruce, yet much less tolerant than Engelmann spruce, black spruce, and red spruce. Seedlings and young trees endure but little shade without a material check to their growth, the most vigorous and full development occurring only in full light.[1] With top light saplings and older trees are able to endure considerable side shade.

Blue spruce is an abundant seeder, producing full crops of cones at intervals of 2 or 3 years. The seed has a rather high rate of ger-

[1] Much disappointment is experienced by those who use this tree for ornament because it does not continue to maintain a full, vigorous crown when planted under the shade of older trees or in close groups. The best form can be produced only by planting single trees, or groups of trees widely spaced, so that they will have full enjoyment of sunlight.

PICEA PARRYANA: FOLIAGE AND RIPE CLOSED CONES.

a, Detached large form of open cone; *b*, mature leaves of new shoot; *c*, seedlings two weeks and one month old.

PICEA PARRYANA: FOLIAGE AND PARTLY OPEN CONES.

a, Upper (lower row) and lower sides of seeds with wings; *b*, detached leaves showing variation in shape and length (two and one-half times larger than natural size).

mination and persistent vitality. Reproduction, however, is generally scanty and confined mostly to exposed mineral soil in the immediate vicinity of seeding trees. Scanty reproduction elsewhere near mother trees probably is due to the fact that the light seed is prevented from coming in contact with mineral soil by the dense herbage and other ground cover abundant in the habitat of this spruce. Only seldom is abundant reproduction seen where a seed crop chances to fall on earth slides or on moist soil otherwise exposed.

LONGEVITY.

The blue spruce is apparently a very long-lived tree, some of the largest trees probably being not less than 400, and possibly 600 or more years old. Diameter growth is often extremely slow, trees 4 to 5 inches in thickness having attained an age of from 125 to 135 years, while trees 18 to 22 inches in diameter are from 275 to 350 years old.

GENERIC CHARACTERISTICS OF BALSAM FIRS.[1]

The true balsam firs are evergreen trees with conical, often sharp spirelike, dense crowns of heavily foliaged branches, which by side branching form wide, flat sprays. They are medium to very large size trees with very straight trunks, which gradually taper to one or two slender leaders. Whorls or circles of rather short small branches grow from the trunks at regular, distant intervals. The cone-shaped or arrowlike heads and straight stems of these trees usually distinguish them at a distance from all other associated conifers. Before the trunk bark is broken or furrowed by age, it is marked by many horizontally elongated, blisterlike resin pockets, which are formed just beneath the smooth surface. These resin pockets are often an inch or more long, and so numerous as to be very conspicuous. No other native trees have this characteristic so plainly marked.[2] It seems probable that trees of this group were given the popular names "balsam" and "balsam fir" because of the liquid resin which is obtained from the pockets of some species for medicinal and mechanical purposes.[3] The winter buds of our native

[1] The class and family relationship of the firs to other cone bearers is fully discussed by the writer in Bulletin 207, U. S. Department of Agriculture, "The Cypress and Juniper Trees of the Rocky Mountain Region," 1915.

[2] Small resin blisters are sometimes formed in the smooth bark, especially of the upper stems, of young Douglas fir (*Pseudotsuga taxifolia*) and Engelmann spruce. They are, however, rarely, if ever, as large or as numerous on these trees as the "blisters" formed in the bark of true balsam firs (Abies). The author is indebted to Prof. E. E. Carter for calling attention to the occurrence of resin blisters in the bark of Engelmann spruce he observed growing in Colorado.

[3] In this country the crude resin, commonly called "Canada balsam," is obtained entirely from one species of fir (*Abies balsamea*), and chiefly, if not wholly, in the eastern Provinces of Canada and adjacent sections of northeastern United States. A similar product, commercially known as "Strasburg turpentine," is collected from the European silver fir (*Abies pectinata*), and also from the Siberian fir (*Abies pichta*). The "blisters" of all other firs yield liquid resin of the same general character, differing, however, in the color and odor, due to differences in chemical composition.

fir trees are, with the exception of one species (*Abies venusta*), coated with resin.

The leaves of firs, spirally arranged on the branches, persist for from 5 to 10 years (usually 9), after which the oldest set of leaves (a season's growth) gradually disappears. Branches from which the leaves have fallen are conspicuously marked by smooth circular scars, points where the leaves were once attached. In this respect the firs differ radically from the spruces, the leaves of which when shed leave a projecting portion of their bases attached to the branch, giving the latter a distinctly rough feel and appearance. Leaves on the lower branches of our native firs are mostly flat (in one species triangular) and rounded, notched, or blunt at the end (one species only having needle-pointed leaves). In some species the leaves of lower branches appear to grow more or less distinctly in two ranks (somewhat like the teeth of a comb) on opposite sides of the twigs (Pl. VII), while in other species they clothe the top of the branch (Pl. X). The firs that have a distinctly two-ranked arrangement of their foliage on the lowest branches produce leaves on their middle and upper-crown branches which appear more and more to grow only from the upper sides of the twigs. In the case of firs whose leaves thickly clothe the upper sides of the lower branches there is little change from this arrangement in the middle and upper crown. In all cases, however, leaves of the extreme upper branches are stouter, crowded, and strongly curved toward the upper side of the horizontal twigs, and often keenly pointed or somewhat sharp-pointed (Pl. IX). The stout leaders also have larger, keenly pointed leaves (Pls. VIII, *a* and XII, *a*). It is important, therefore, to note the very dissimilar form, habit, and character of leaves in these three parts of the crown, for leaves of the middle-crown branches (Pl. VIII, *b*) are sometimes different in form and arrangement from those of either the lower or upper crown branches. A cross section of the leaves of firs shows two resin ducts (a distinctly marked ring of cells) usually near the lower surface and close to the edges. In the case of some of our firs, however, these ducts are in the interior of the leaf's tissue, about midway between the upper and lower surface of the leaf.[1] The under surface of the leaves has one or several rows of stomata or minute pores on each side of the raised midrib, and sometimes also on the upper surface.

[1] Resin ducts are scarcely visible to the naked eye, but they can be readily seen in a thin cross section or slice of a fresh leaf viewed under a simple pocket lens. The location of resin ducts is always indicated by two minute drops of resin which ooze from the ducts when a fresh leaf is cut in two. As a rule there is little variation in the characteristic position of resin ducts in leaves taken from different parts of the tree. In the case of three exotic firs (*Abies nordmanniana, A. cephalonica,* and *A. pectinata*) resin ducts of the lower and middle-crown branches are near the margin of the leaves, while in leaves of the topmost or fruit-bearing branches the ducts are situated in the interior of the leaf's tissue. (Fide cf. Guinier and Maire, Bull. Soc. Bot. France, LV, 189, 1908.)

The male and female flowers of the firs are produced on different branches of the same tree. Each sort is borne on branchlets of the previous year's growth, the male flowers on the lower-crown branches and the female flowers on the topmost branches of the same tree. Male flowers, which bear pollen, are elongated, cylindrical, scaly bodies hanging singly among the leaves from the lower side of branches. The female flowers, which produce cones and seeds, are short, spherical, rounded or elongated, scaly bodies standing erect and singly on branches of the uppermost part of the crown. The cones, whose erect or nearly erect position is unique and distinctive of all firs, mature in one season. (Pls. IX, XI, and XII, *b*.) During autumn their thin, closely packed, overlapping scales gradually become loosened from the central spikelike axis (Pl. IX, *c*, and Pl. XXIII) and fall away with their winged seeds, two of which are borne under each scale (Pl. XIV, *b*, and Pl. XVII, *b*); no fertile or perfect seeds are borne under scales at the two ends of the cones. The spikelike woody axes of the cones remain attached to their branches for several years. (Pls. IX, *c*, and Pl. XII, *b*.) Morphologically these woody axes are modified twigs. The breaking up of mature cones on the trees is characteristic of no other group of our cone bearers, except the deciduous-leafed Taxodium ("cypress") of south Atlantic forests. As the ripe cones of firs break up strong winds may blow the seeds several hundred feet from the parent trees, but as a rule the seeds fall near the mother tree or are wafted not more than 50 or 100 feet away. The seeds have peculiar resin cells, which may be seen by cutting into the seed coat. Under ordinary conditions the vitality of fir seeds rarely, if ever, endures longer than a single season, and as a rule the percentage of germination is comparatively low (50 per cent or less). Seed-leaves (cotyledons, the first foliar organs to appear when the seed germinates) range from 4 to 10 in number and are flat. (Pl. XXIII, *c*.)

Fir trees are of great commercial importance on account of the excellent saw timber the larger species produce, while some of them are important also because they form protection forests on steep slopes at high elevations where few other conifers can live. They are moderately long-lived trees, their age limit ranging from about 200 to 350 years; much is yet to be learned, however, concerning their longevity.

Eleven species of firs inhabit the United States. Six of them occur within the Rocky Mountain region (of the United States and Canada), while four are common to both the Rocky Mountain and Pacific slope regions. One species ranges from the Canadian Rocky Mountain region eastward to the Atlantic coast, where it is common both in our northeastern States and in adjacent parts of Canada. One of

our firs is confined to eastern United States, four to the Pacific slope, and one to our Rocky Mountain region.

The fir trees were represented in geologic times.[1] Many fossil species, not now represented by living forms, are widely distributed from the Upper Eocene to the present. Remains also of an Abieslike group of trees (*Abietites Hisinger*) are very common in the Lower and Upper Cretaceous periods.

BALSAM FIR.

Abies balsamea (Linn.) Miller.

COMMON NAME AND EARLY HISTORY.

The balsam fir does not occur in our Rocky Mountain region, but is found within the Canadian Rocky Mountain region, and for purposes of completeness is included here without reference to political boundary. Balsam fir extends southward into the United States only from the Great Lakes and north Atlantic regions (Map No. 5). It is locally known in this wide range by a dozen or more common names, the most appropriate of which is "balsam fir," coined from the tree's technical name.

The first published reference to balsam fir appeared in 1664 and was by Pierre Boucher,[2] who observed it in eastern Canada. The earliest mention of this fir in New England is by John Josselyn,[3] who recorded its characteristics ("bark is smooth, with knobs or blisters in which lyeth clear liquid turpentine") in 1673. Balsam fir has the distinction of being the first of North American firs to become known to science, the earliest technical name applied to it being "Pinus balsamea Linneus," published in 1753, and on which the present name of this fir, Abies balsamea, is based. The tree was, however, cultivated in English gardens as early as 1704, when John Ray, an English writer, published a brief description[4] in Latin of its botanical characters, but without, as was customary then, giving a technical name to it. The early settlers of eastern Canada and northeastern United States were evidently well acquainted with the balsam fir, for French and English settlers and explorers of those regions described the tree and its resinous product in works published long before it was known to scientific writers.[5]

The botanical history of balsam fir extends over 160 years and includes the application at various dates of 17 different specific and

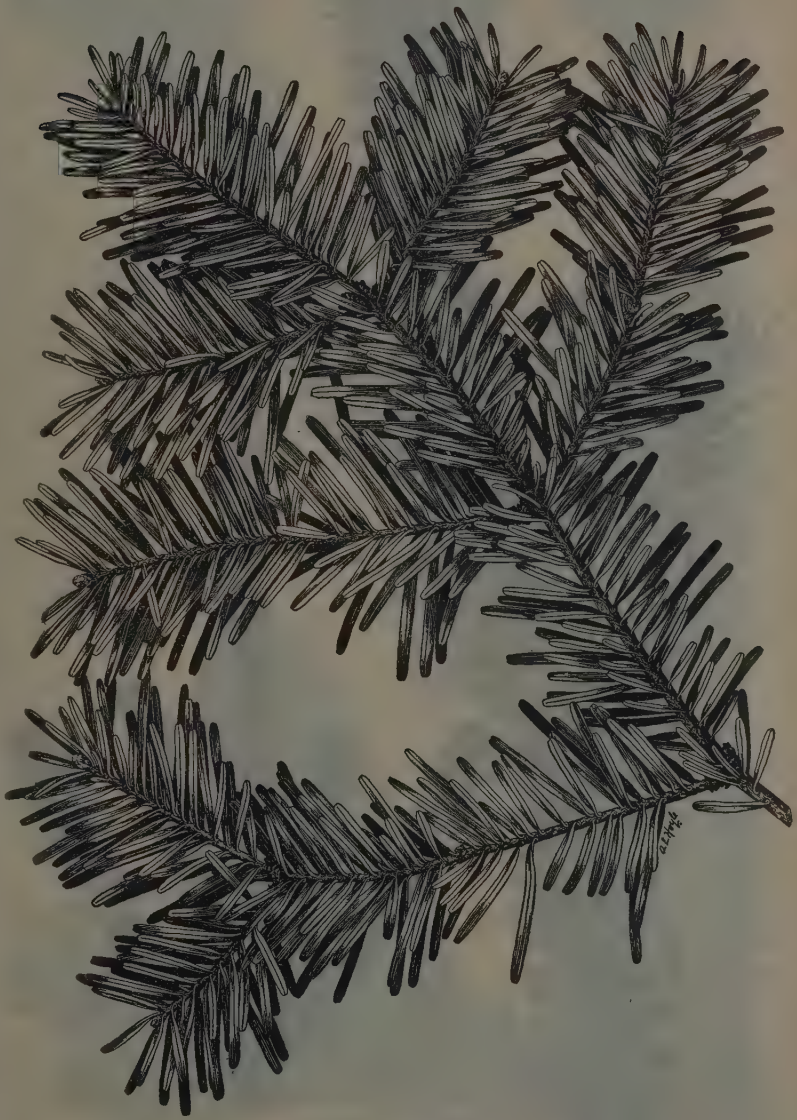
[1] Fide Dr. Edward W. Berry. See footnote, p. 3.

[2] Hist. Veritable et Nat. de Moeurs et Prod. du Pays de la Nouvelle France * * * le Canada, ed. 3, 49, 1664.

[3] An account of Two Voyages to New England, 65 (ed. 1), 1673.

[4] "Arboris Balsamum Gileadense fundens," Historiæ Planatarum, Lib. XXV, Dendr. Secundus, p. 8, Vol. III, 1704, by John Ray.

[5] Balsam fir is said to have been grown for ornament in England as early as 1697, and in Norway in about 1772, where it attained a height of from 50 to about 65 feet.



ABIES BALSAMEA: LOWER-CROWN BRANCH.

ABIES BALSAMEA.

a, Terminal shoot ("leader") showing characteristic short, keenly pointed leaves; *b*, middle-crown branch.

ABIES BALSAMEA: FOLIAGE AND RIPE CONE.

a, Lower side of cone scales with bracts; *b*, upper side of cone scale with one seed in place and upper (right) and lower sides of seeds with wings; *c*, central woody axis of cone from which seed-bearing scales have fallen.

varietal technical names, 6 of which are now reduced to synonymy, and 11 of which (varietal names) distinguish garden or cultivated forms of the tree. These varietal forms are distinguished mainly by differences in the habit of growth, form and size of the crown, and by the color and length of the leaves. One of the best marked of these varieties is a very much dwarfed plant, Abies balsamea hudsonia (Knight) Veitch, originally found growing at high elevations. Abies balsamea var. macrocarpa is a form with longer leaves and larger cones than are borne by the ordinary type of this fir, and was raised from seed of trees found in the region of Wolf River, Wis.

DISTINGUISHING CHARACTERISTICS.

Abies balsamea attains a height of from 25 to 75 feet (under the best conditions for growth), and a diameter of from 10 to 28 inches; exceptional trees are somewhat taller and of slightly larger diameter. Smaller trees, including almost stemless prostrate forms, occur in exposed high places and in other unfavorable situations.

The crown form of young trees growing in the open is broadly conical and ends in a long, sharp point. The branches are slender, regularly arranged in distinct circles or whorls about the trunk, and extend down to the ground. In older trees the lower branches hang down slightly, while those of the upper crown trend upward. When balsam fir grows in a dense stand, the long lower-crown branches are soon shaded out, leaving the gradually tapered trunk clear for one-half to two-thirds of its length and surmounted by a short, rather narrowly conical, sharp-pointed crown. The bark on the lower trunks of mature and middle-aged trees is about one-half inch thick, dull red-brown, and superficially divided into small, rather easily detached, thinnish scales. The bark of young trees, and also of the upper stems of old ones, is smooth and ash-colored and thickly set with resin "blisters,"[1] which, as the bark becomes thicker and older, are gradually dried up and finally obliterated. Young twigs are covered with very fine, short hairs, which adhere until the branchlets are about 3 years old. The mature spherical buds, one-eighth to three-eighths of an inch in diameter, are slightly resinous.

The mature leaves are deep blue-green, shiny on the upper side, and conspicuously whitish (with rows of stomata) on the under side, the latter becoming less bright after the leaves are 2 or 3 years old. Leaves of the lower-crown branches (Pl. VII) differ, as a rule, very greatly in their form and arrangement[2] on the twigs from both those

[1] The so-called "Canada balsam" of apothecary shops is the crude oleoresin obtained from these pockets or blister-like cavities by puncturing the thin overlying bark and squeezing the contents into a small-mouthed receptacle. Gathering this resin constitutes an industry of considerable importance, especially in eastern Canada.

[2] Occasional trees are found, especially in the western range of this tree, on which the leaves are more or less crowded on the upper sides of the lower-crown branches, somewhat as in Plate VIII, *b*.

of the middle-crown branches (Pl. VIII, *b*) and of the upper or cone-bearing branches (Pl. IX), while the thinly set leaves of the terminal shoot or "leader" are strikingly different from all of the other foliage (Pl. VIII, *a*). In length the leaves vary from about 1¼ inches on the lower and middle-crown branches to about five-eighths of an inch on the topmost branches. A slightly magnified cross section of the leaf shows two resin ducts, one in each end of the section (edge of leaf), slightly nearer to the lower surface of the leaf.

Mature cones (Pl. IX), which are fully grown and ripe by September, are from 2 to about 4½ inches long and from seven-eighths of an inch to 1 5/16 inches in diameter. At first the ripe cones are externally deep purple, which later become paler as the scales are loosened by drying and fall away from the cone's central axis (Pl. IX, *c*). The bracts attached to the backs of the cone scales (Pl. IX, *a*) are only about one-half as long as the scales. Sometimes, however, the points of all of these bracts extend slightly beyond the ends of the cone scales, while in rare instances some of the cones of a tree may have extended bracts and other cones hidden bracts. The seeds (Pl. IX, *b*) are pale yellowish-brown, as are also the shiny wings.[1]

Balsam fir wood is usually of very light weight, soft, and brittle. It is rather wide-ringed in the faster-growing trees of open stands, and narrow-ringed in the slower-growing trees of dense stands. Seasoned wood weighs approximately 23.8 pounds per cubic foot, ranking second in weight among the other Rocky Mountain fir woods. The sapwood is whitish and from 1 to 2 inches thick, while the heartwood is light yellowish brown, sometimes marked with yellow areas. In the central and eastern part of the tree's range the wood is extensively used, in mixture with spruce wood, for paper making. It is also much used for box boards, being rarely cut into other lumber because of its soft texture, knotty character, and lack of durability.

OCCURRENCE AND HABITS.

Throughout its wide range balsam fir grows in soils and under climatic conditions that are quite dissimilar (Map No. 5). In the main, however, it demands an abundance of soil moisture and a humid atmosphere. Lack of these conditions limits its occurrence or greatly impairs its growth. It is most common and of largest size in rich well-drained bottom lands and on adjacent high ground about lakes and water courses, being less common and of smaller size in swampy and low ground, on low hills and benches, on high ridges, and at or near low timber line. The vertical range of balsam fir

[1] The only other Rocky Mountain fir that could be confused with the balsam fir, and then only in Canadian territory, is the alpine fir, which is somewhat similar in size and general appearance. The larger, longer, crowded, upright lower-branch leaves of alpine fir, however, and the horny, little-broken trunk bark of large and medium size trees serve to roughly distinguish this species from balsam fir, the lower-branch leaves of which are commonly arranged on two sides of the twigs, while its trunk bark is loosely scaly.

varies from elevations near sea level to over 5,600 feet. Only low, almost prostrate forms occur, however, at high elevations. The largest trees of this species occur in eastern Canada and in our Northeastern States. In the Canadian Rocky Mountain region balsam fir is a much smaller tree, often closely associated with white spruce, while jack pine, tamarack, black spruce, balm of Gilead, aspen, and paper and mountain birches occur more or less within the same region and are often interspersed with it. Small groups and pure stands of very limited extent occur frequently in deep, rich moist soils of depressions, coves, along streams, and about lakes and ponds.

During the first 6 or 8 years of its life balsam fir is able to grow thriftily in the dense shade of other trees, but during the remainder of its life it requires nearly full top light for the best delevopment. It is much more tolerant of shade in moist soil than in dry situations. Trees continue to live under deep shade for a very long period, but with extremely slow growth. If overhead light is admitted during the period of suppression, the trees recover quickly and resume their normal rapid growth.

Seed is borne abundantly at intervals of 2 and 3 years, and sometimes of 4 years, while considerable seed is produced every year. Trees growing in full enjoyment of the light bear much heavier crops of cones than do those in close stands. Trees long suppressed by shade do not produce seed, doubtless because of the practically arrested growth of the "leader" and upper crown, the only part of the tree that normally produces cones. Pole-size trees (20 to 25 years old) bear a small number of cones, the amount of seed produced increasing as the trees grow older.

The seed has a low rate of germination (15 to 30 per cent) and very transient vitality. Germination occurs plentifully in openings and under the deep shade of the mother trees, where dense groups and thickets of seedlings are frequent as a result of a copious fall of seed. Seedlings are also often thinly scattered. The seed germinates readily in moist exposed soil and humus, but most abundantly on moss-covered decayed logs, in sphagnum, and among other dense herbage, where the even supply of moisture affords the most favorable conditions. Reproduction is always scanty in drier situations. Branches of balsam fir layered in moist soil sometimes strike root, occasionally producing new plants by this vegetative method.

LONGEVITY.

Balsam fir is comparatively short-lived, the largest trees probably not attaining a greater age than 150 years. Dominant trees in a close or open stand grow much more rapidly in diameter than do trees in a close even-aged stand. Diameter growth is still slower in

even-aged stands when the latter are more or less suppressed. Dominant trees 6 inches in diameter in an open stand are about 30 years old, while dominant trees of this size grown in a dense stand are from about 40 to 120 years old. Trees 16 inches in diameter that have grown in an open forest are about 130 years old, while dominant trees 12 inches in diameter grown in a close stand are about 156 years old. Suppressed trees 6 inches in diameter may be from about 50 to 75 years old, according to the density of overhead shade. In exceptional cases wholly suppressed trees 2 to 3 inches in diameter may be from 75 to 100 years.

ALPINE FIR.

Abies lasiocarpa (Hook.) Nuttall.

COMMON NAME AND EARLY HISTORY.

Alpine fir is one of the smallest of the western firs and perhaps also one of the least known there, owing to the fact that it grows chiefly at high altitudes. The common name, "alpine fir," adopted here, would seem to be the most appropriate one for this species, because it refers to the tree's high mountain habitat.[1] Woodsmen and settlers usually call it "balsam" or "mountain balsam."

It is probable that alpine fir was first discovered in September, 1805, by Lewis and Clark, while crossing the Bitter Root Mountains (whether on the Montana or Idaho side is unknown), for the narrative[2] of their exploration of our Northwest mentions "a growth of eight different species of pine," which by exclusion must have included this fir.[3] To David Douglas belongs the credit of having first collected a specimen of this fir in 1832 in the "interior of N. W. America." On this specimen is based the first published technical description and name of the tree, "Pinus (Abies) lasiocarpa Hooker," published in 1839, and on which the present name, Abies lasiocarpa (Hooker) Nuttall, is founded. Dr. C. C. Parry[4] seems to have been the first to find alpine fir in our central Rockies (Colorado), where he observed it in 1862, and from which in 1863 he distributed seed.[5] It was not known, however, until 1876 that the

[1] Abies lasiocarpa is frequently called "balsam fir," probably because of its general resemblance to the true balsam fir (*Abies balsamea*), to which, however, this name properly belongs, having been applied to it long before the alpine fir was known to botanists.

[2] History of the Expedition under Command of Lewis and Clark, 1804–1806 (ed. Dr. Elliott Coues), II, 598.

[3] It was common in the early days, even for botanists, to designate as "pine" the trees we now know as firs.

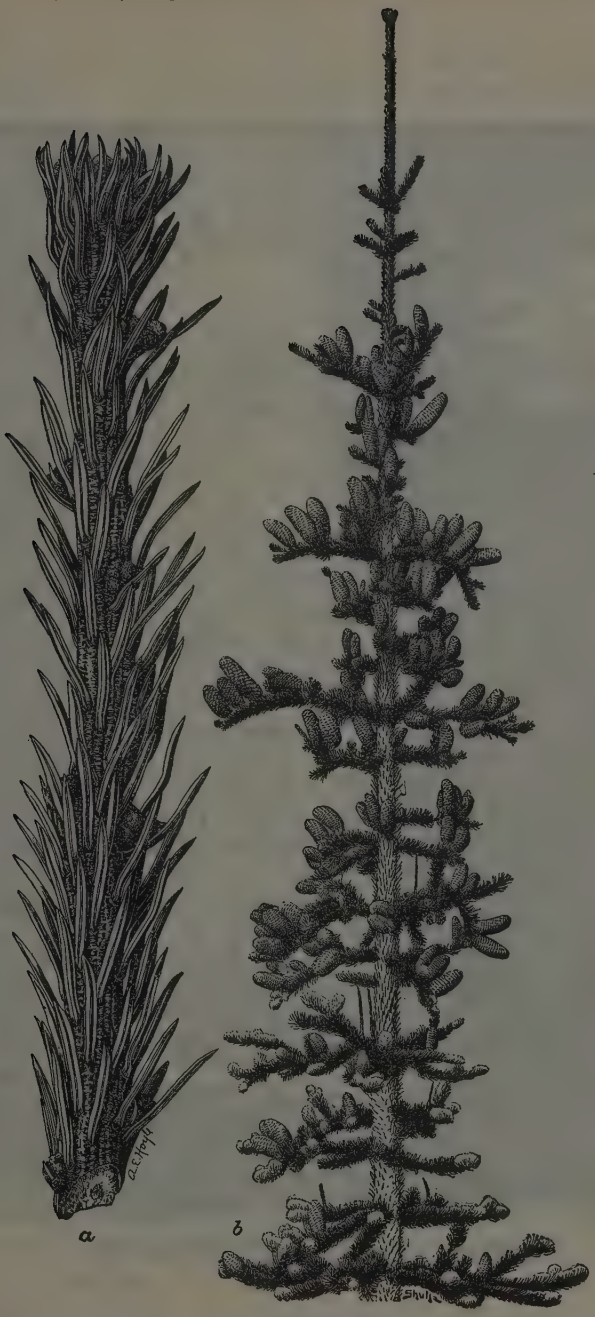
[4] Engelmann in Am. Nat., 555, 1876.

[5] There appears to be no record of plants raised from this seed. Probably the first trees known in cultivation were grown from seed planted in 1873 in the Arnold Arboretum, Massachusetts. Their growth in height for the last 40 years has, however, been exceedingly slow, amounting to only about 3 or 4 inches per year. Alpine fir seems to have been introduced into England in about 1890, but according to Elwes and Henry (Trees of Great Britain and Ireland, IV, 803, 1909) its growth there has been practically a failure. The German Government imported seed of this fir for forest experiments in the early nineties, and these trials show the tree to be better adapted to the climate of Germany than to that of England.

ABIES LASIOCARPA: LOWER-CROWN BRANCH.

ABIES LASIOCARPA: FOLIAGE AND RIPE CONE.

a, Lower side of cone scales and their bracts, showing variation in form of latter; *b*, lower side of seed; *c*, upper side with wings.



ABIES LASIOCARPA.

a, Terminal shoot ("leader") showing characteristic sharp-pointed leaves; *b*, top of tree showing ripe cones and naked cone spikes of previous year's crop.

ABIES LASIOCARPA: TYPICAL BARK OF MATURE TREE.

tree he saw there is the same as Nuttall's Abies lasiocarpa.[1] A cultivated variety of alpine fir, Abies lasiocarpa caerulescens, was described in 1891 by a German dendrologist. This form is distinguished by the deep silvery-blue tint of its foliage, a characteristic which is, however, largely lost as the leaves become fully mature, and is not as marked in older trees as in young ones.

DISTINGUISHING CHARACTERISTICS.

The long, narrowly conical crown, terminating in a conspicuous spearlike point (Pl. XII, *b*), at once distinguishes this fir from all associated species of its kind in the region, its sharp-pointed heads being recognizable at a long distance. The height attained is ordinarily from 60 to 90 feet and the diameter is from 14 to 24 inches, but in exposed high situations the stems may be under 4 feet in height, with very long lower branches resting on the ground. Rare old trees attain heights of from 100 to 130 or, very occasionally, 160 feet and a diameter of 3 to 4 feet. Still larger trees are reported, but they are exceedingly rare. The trunk bark is thin, at most about 1¼ inches thick, hard, flinty, and but little broken even on fairly large trees, except occasional shallow, narrow cracks near the base of the trunk (Pl. XIII). The unbroken smooth areas of bark are ashy gray—often chalky-white. Even on old trunks, always irregularly and shallowly seamed, the flat ridges of bark are whitish, but pale-brownish in the seams, while the inside of the bark is red-brown.

In open stands the narrow crowns of both young and old trees usually extend down to the ground. In very close stands the trunks of old trees are occasionally free from branches for from 20 to 40 feet or more (Pl. XIII). The dense, characteristically tough branches at the base of the crown droop, and later when they die they are often sharply curved or bent down upon the trunk.[2]

The foliage is deep blue-green, that of each season's growth having a silvery tinge. The twigs are usually covered with minute, rusty hairs for 2 to 3 years, or sometimes they are smooth. The winter buds are covered with resin. The flat leaves, pointless and longer on lower-crown branches (Pl. X), and keenly or somewhat pointed and shorter on uppermost branches (Pl. XI), are distinctly massed and pointing upward on the top side of the branches, those below and on the sides of the branches being curved so as to joint those above. This dense

[1] Dr. George Engelmann (l. c.) described and named this fir "Abies sub-alpina" in 1876, a name which is now a synonym of the earlier published A. lasiocarpa (Hook.) Nuttall.

[2] The low branches make this fir particularly subject to crown fires, which invariably kill large numbers of trees, while the thin bark of the trunk is also frequently injured or killed by severe ground fires.

crowding and upright position of the leaves on the upper sides of the branches is very characteristic. Leaves of the "leader" or topmost central stem (Pl. XII, *a*) are sharply pointed and scattered.

Mature cones of the alpine fir are from 2¼ to about 4 inches in length by about 1¼ to 1½ inches in diameter (Pl. XI); after the cone scales become loosened by drying out, the cones are considerably larger in diameter. Ripe cones are deep purple at first, gradually becoming lighter by the time the scales fall. The cone scales bear bracts (Pl. XI, *a*), which are abruptly rounded or contracted at the free end to a slender central point. The ivory-brown seeds (Pl. XI, *b*) have large, shiny, purplish, or violet-tinged wings. The seed-leaves, one-third to one-half an inch long, are usually 4 in number.

Alpine fir wood is lighter in weight than that of any other Rocky Mountain fir, a cubic foot of dry wood weighing about 21.66 pounds. It is narrow-ringed, soft, and from pale straw-color to light yellowish brown. As a rule, the wood is fairly straight-grained and splits and works easily, but it rots rapidly in contact with earth. However, the fire-killed, deeply season-checked shafts of this tree, so frequent where forest fires have swept the ground, may remain sound above ground for many years. Dead timber is locally much used for fuel, house logs, and corral poles. Occasionally green timber is sawed into rough lumber for local use. Little clear lumber is, however, obtainable even from large trees, because during the greater part of life the lower trunk branches are retained down to the ground.

OCCURRENCE AND HABITS.

Alpine fir always grows in cool, moist, and, in part, subalpine situations. It occurs commonly on all slopes at timber line, and, at the lower limits of vertical range, in protected valleys, at the heads of streams, and about mountain lakes and moist meadows (Map No. 6). At the North its lowest vertical range is about 3,500 feet, though at the South it may reach an elevation of 10,500 feet. Alpine fir has a narrow range in altitude at the North, where the timber line is relatively low, and at and near which the moisture conditions necessary for its growth are present. Likewise at the South, the vertical range of this fir is narrow, because here the timber line, with the accompanying moisture conditions, occurs only at higher elevations. The best growth occurs on north slopes in fairly deep, loose, moist soil, while much smaller trees are found in the poorest and driest thin soils. It grows also in wet situations, but it does not thrive on heavy, clayey soils. Its main occurrence is limited by requirement of soil moisture to elevations where snowfall is heavy. In general, how-

ever, alpine fir requires less soil moisture than Engelmann spruce, but grows in places too wet for this spruce; it also grows on soils suitable for Douglas fir, where Engelmann spruce will not succeed.

Alpine fir occurs in pure small stands and in mixture with other trees. At the North it is associated more or less with mountain hemlock, Engelmann spruce, lodgepole pine, white-bark pine, limber pine, and Lyall larch. At the south it is mingled commonly with Engelmann spruce, lodgepole pine, cork fir, and aspen, and less frequently with bristle-cone pine.

Alpine fir is only slightly less tolerant of shade than Engelmann spruce, and, except the mountain hemlock, it can live under deeper shade than any of its associates. Saplings long suppressed by heavy shade recover and grow rapidly with the admission of top light.

Abies lasiocarpa is a moderately prolific seeder, beginning to bear cones as early as the twentieth year. Some seed is produced locally every year, but heavy production occurs only at intervals of about 3 years. The seed has a rather high rate of germination, but very transient vitality. Seedlings spring up abundantly on exposed mineral soil in the open and also on thin and heavy moist duff under light or heavy shade. Usually, however, they grow most thickly on the north side of groups of trees or forests and under the branches of mother trees. Abundant reproduction nearly always occurs in shaded openings among seed trees. At high elevations branches lying on the ground and partly covered with earth or moist duff occasionally take root, from which, however, the production of new trees is probably very rare.

LONGEVITY.

Alpine fir is moderately long-lived. Trees from 10 to 20 inches in diameter are from 140 to 210 years old. The considerably larger trees which occur are not likely to be more than 250 years old.

CORK FIR.

Abies arizonica Merriam.

COMMON NAME AND EARLY HISTORY.

Most authors consider this fir a form only or a variety of the alpine fir (*Abies lasiocarpa*). For the present, however, it is here maintained as specifically distinct from the alpine fir, to which it is very similar in crown form and in the general appearance of its foliage, but from which it is at once distinguished by its soft, corky bark (compare Pls. XIII and XV), differences in the shape of the

cone scales and of the bracts[1] (compare Pls. XI, *a*, and XIV, *a*). The book name "Arizona cork fir" has not become established, and can well be replaced now by the shorter and more fitting name "cork fir." "Arizona cork fir" is a name particularly inappropriate, because the tree is not confined in its range to Arizona.

Abies arizonica was first discovered in 1896 by Dr. C. Hart Merriam[2] on a high peak of San Francisco Mountain, Ariz. Since then its range has been considerably extended in Arizona, and the tree is now known to occur in New Mexico and southern Colorado (Map No. 7). Future explorations are likely to extend this range still farther in the southern Rocky Mountain region.

DISTINGUISHING CHARACTERISTICS.

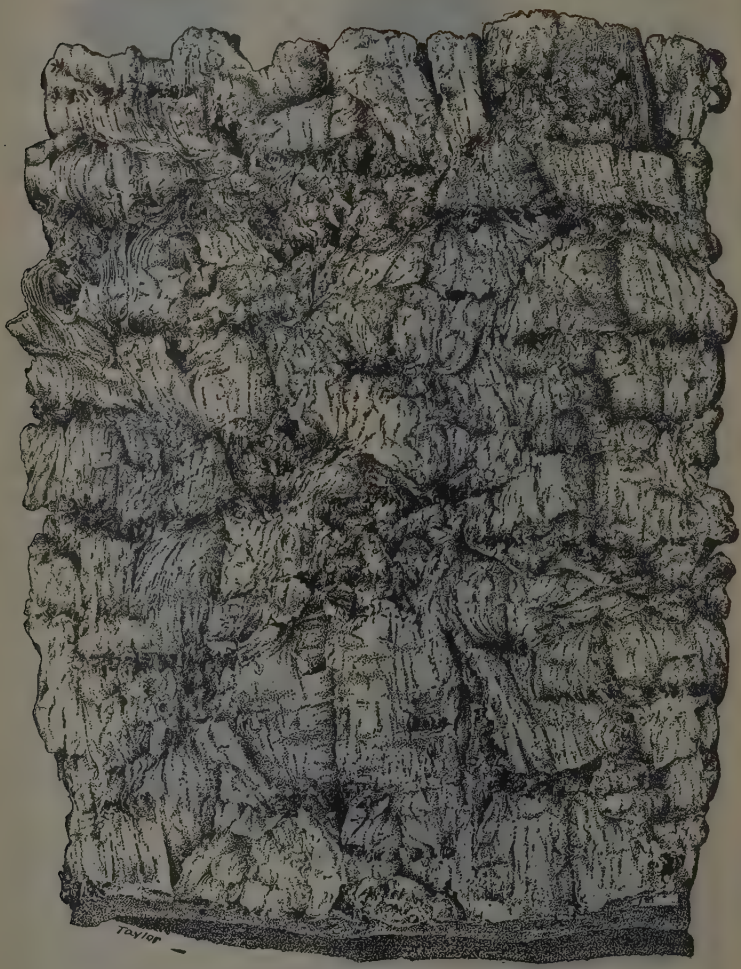
As now known, cork fir attains a height of from 50 to 75 feet and a diameter of from 12 to about 20 inches. Doubtless larger trees occur. The trunk and crown forms are practically the same as in the alpine fir. The yellowish-white or ashy, soft, corky trunk bark (Pl. XV) of Abies arizonica at once distinguishes this tree from A. lasiocarpa (Pl. XIII) and from all other associates. The form and habit of the leaves of the cork fir and Alpine fir are so similar in general appearance that the two trees can not be distinguished by their foliage. The cones (compare Pls. XI and XIV) of the two trees are more or less dissimilar in form and size, but alike in color, and both ripen at about the same time in September. The cone scales of A. arizonica are, however, generally of a distinctly different form (Pl. XIV, *a*) from those of A. lasiocarpa (Pl. XI, *a*), while

[1] Writers who hold this tree to be a form only of the alpine fir seem not to give due weight to the fairly constant difference in the form of the cone scales and bracts of the cork-barked tree as compared with the shape of cone scale and bracts peculiar to the alpine fir. The specific importance of the distinctly corky bark of Abies arizonica is also denied by citing the occurrence of similar corky bark of southern Rocky Mountain forms of white fir and of Douglas fir, and, furthermore, that corky-barked Alpine fir trees occur far north and west of the present range claimed for Abies arizonica. While it is true in general that the bark of many trees is so variable in character as not to afford a reliable specific distinction, it is true nevertheless that a large number of trees have barks of very distinct character. I have often seen Douglas fir and white fir in the Southwest, especially in dry, exposed situations, with corky bark, but not of the distinctly corky nature of bark produced by Abies arizonica. I believe, however, that the corky bark of Douglas fir and white fir is the result of arid conditions, which appear to affect young trees, the corky bark so formed later becoming harder as these trees grow older. In the case, however, of A. arizonica, I do not know that the bark ever becomes harder or less corky. Taking into account the fact that the cone scales and bracts of A. arizonica are usually distinct in form from those produced by A. lasiocarpa, I am confident that the occurrence of corky-barked Douglas fir and white fir trees is a circumstantial coincidence rather than proof that A. arizonica is only a corky-barked form of A. lasiocarpa. I have never seen the cork-barked alpine fir trees reported as occurring north of Colorado and elsewhere outside of the present recorded range of A. arizonica. I should be inclined to believe, however, that these trees represent Dr. Merriam's Abies arizonica, rather than corky-barked forms of A. lasiocarpa. Otherwise I am unable to satisfactorily explain why, in Colorado, New Mexico, and Arizona, A. arizonica occurs side by side with the distinctly hard-barked A. lasiocarpa, a fact which would seem to indicate that the cork-barked tree is inherently different from its associate.

[2] Proc. Biol. Soc. Washington, X, 115, figs. 24, 25, 1896.

ABIES ARIZONICA: FOLIAGE AND RIPE CONE.

a, Lower side of cone scales and their bracts; *b*, upper side of cone scale with its winged seeds (as they are borne) and detached seed; *c*, lower side of seed.



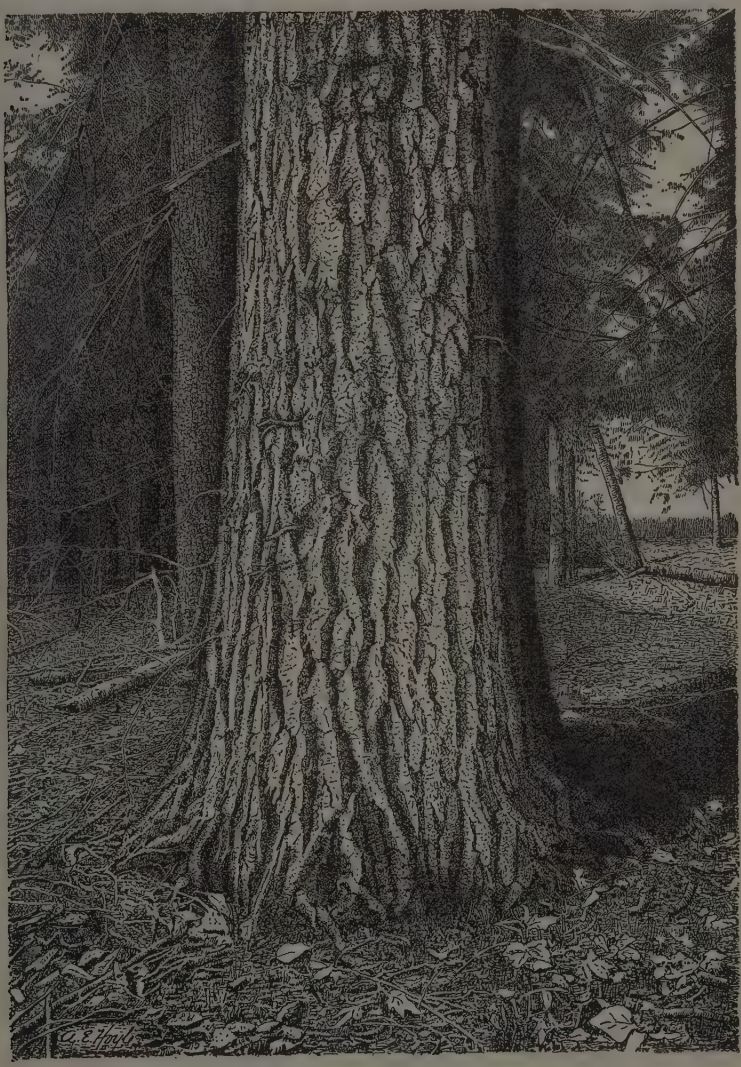
ABIES ARIZONICA: SECTION OF TYPICAL CORKY BARK OF TRUNK.

ABIES GRANDIS: LOWER-CROWN BRANCH.

PLATE XVII.

ABIES GRANDIS: FOLIAGE AND RIPE CONE.

Lower side of [illegible] showing various forms of their bracts; b, upper side of cone scale and its winged seeds (as they are borne); c, lower side of seeds;



ABIES GRANDIS: TYPICAL BARK OF TRUNK.

ne bracts borne on the backs of the cone scales of both trees also iffer materially in form. No constant distinguishing characters an be found in the seeds (Pl. XI, *b*, *c* and Pl. XIV, *b*, *c*). The seed-eaves of cork fir are commonly four in number, and about one-half n inch long.

The wood of Abies arizonica is similar in external appearance to nat of alpine fir and useful for the same purposes. It is commer-ially unimportant, except where the timber can be cut with alpine r, from which when sawed into lumber it can not be distinguished n its general appearance.

OCCURRENCE AND HABITS.

Cork fir grows on disintegrated rock and in gravelly soils or on ninly covered rock at elevations between about 8,000 and 10,000 eet, and usually on northern slopes and benches, but sometimes on xposed ridges and high peaks (Map No. 7). In some instances it orms nearly pure groups or stands of limited extent interspersed rith Engelmann spruce and alpine fir, or is scattered in dense stands f the latter tree. Not infrequently very widely separated trees are ound in a mixed stand of Engelmann spruce and alpine fir.

Cork fir is equally as tolerant of shade as the alpine fir, young rees maintaining themselves for many years under dense shade in a ompletely suppressed condition. But with the admission of top ight such growths readily recover and grow rapidly.

Little is known at present of the seeding habits and reproductive apacity of this fir. An abundance of cones are produced periodi-ally—usually about every 3 years, while some trees bear a few cones early every year. Only a small percentage of the seeds are fertile. The ripe cones are "cut down" by squirrels, along with those of the ssociated alpine fir, and a good many seeds are eaten by these odents. Small dense patches of suppressed seedlings are frequent ear fruiting trees, particularly in the washed soil of depressions and n the soil-filled crevices of exposed rock on northern slopes.

LONGEVITY.

The age limit of cork fir is imperfectly known at present. Like lpine fir it is probably only a moderately long-lived tree, not exceed-ng 150 to 175 years. Trees from 6 to 12 inches in diameter are from 5 to 90 years old.

GRAND FIR—"WHITE FIR."

Abies grandis Lindley.

COMMON NAME AND EARLY HISTORY.

Lumbermen and other woodsmen know this tree commonly as white fir," because of the whitish, smooth bark of its upper stem.

The name white fir, however, belongs more properly to Abies concolor, for which it is probably more commonly and widely used than for any of the other white-barked western firs. It is probable that lay people often apply the name white fir to A. grandis believing it to be A. concolor. In the absence of a distinctive common name for A. grandis, "grand fir," derived from the tree's specific technical name, is adopted here as suitable, because Abies grandis is a very stately and grand tree when fully matured.

Lewis and Clark[1] were probably the first to discover the grand fir in 1805 while crossing the Bitter Root Mountains, this tree doubtless being one of the "eight different species of pine" mentioned in their narrative. David Douglas, an intrepid Scotch explorer of our Northwest, is said to have found this fir near the mouth of the Columbia River in 1825, seeds of which he sent to England in 1831 or 1832.[2] The grand fir was first technically described and named Abies grandis Lindley in 1833, since which time this name has been uniformly maintained by botanists. Some early writers, however, confused grand fir with the white fir (*Abies concolor*), while even now a few students of trees find difficulty in distinguishing the two species where their ranges come together.[3]

Two horticultural varieties of grand fir, Abies grandis aurifolia and A. grandis crassa, have been distinguished in cultivation by a German dendrologist. The first of these is characterized by its yellowish foliage and in the other form by the compact shape of its crown.

DISTINGUISHING CHARACTERISTICS.

In such favorable situations as moist bottom lands grand fir grows to a height of from 150 to 200 and, exceptionally, 250 to 275 feet, with a diameter of from 3 to 4 feet. Somewhat taller trees occur, but they are rare. On the less favorable hill lands the greatest height attained is from 80 to 125 feet, with a diameter of from 18 to 30 inches. The trunk is remarkably straight and tapers very gradually. When standing alone or in an open forest even old trees often retain their branches down to within a few feet of the ground; but in a close stand the crown covers only one-half or one-third of the stem. The crown is a narrow, rather open cone, pointed in young trees and somewhat rounded at the top in old ones. Because of the strong drooping of the lower branches, the crown of old trees appears wider in the middle. The rounded top of well-advanced

[1] History of the Expedition under Command of Lewis and Clark, II, 457 (ed. Coues).

[2] Elwes and Henry, Trees of Great Britain and Ireland, IV, 774, 1909.

[3] Abies grandis was first introduced into England in about 1831, and, according to Elwes and Henry (l. c.), it grows best of all of our fir trees in England, Scotland, and Ireland, where there are many trees 80 to 90 feet high planted 40 to 50 or more years ago. It is also said to thrive in parts of Denmark and Germany.

trees results from the cessation of height growth in the leader and an elongation of the older, shorter, upper side branches. All of the branches, except the topmost, have a distinct downward and upward swing. The bark, peculiarly characteristic in this species, is smooth and ashy-brown, with chalky areas on young trunks and regularly and shallowly furrowed on older trees, the long, flat ridges still retaining splashes of gray-white. (Pl. XVIII.) The bark of very old trees is still more deeply but narrowly furrowed, the ridges being sharper and less conspicuously flecked with white and the general tone pale red-brown with an ashen tinge. In texture the bark is very hard, close, and horny. It is rarely over 1¾ inches thick on old trunks and scarcely an inch thick on trees from 18 to 20 inches in diameter.

The deep yellow-green shiny foliage of grand fir is somewhat thin in appearance because of the characteristic two-ranked arrangement of leaves on the lower branches. Leaves on these branches are flat, grooved above, blunt, and nearly always distinctly notched at their ends (Pl. XVI). They appear to grow only from two opposite sides of the branches, but many of the leaves are brought into this position by a twist at their bases. Leaves of the lower-crown branches are from about one-fourth inch to 2¼ inches long. Leaves of the uppermost branches also are often notched; but here they are usually crowded together in a more or less upright position on the top sides of the sprays and are from about 1 to 1½ inches long (Pl. XVII). The scattered leaves of the leader are sharp or keenly pointed and from one-half to seven-eighths of an inch long. All leaves are conspicuously white on their under surfaces. The mature winter buds are covered with resin, and the twigs of the season are pale russet-brown and minutely hairy.

The cones of this fir mature in early autumn, and are very characteristic in their clear, light yellow-green color and slender, cylindrical form (Pl. XVII). They are about 2½ to 4¼ inches long and about 1 to 1⅓ inches in diameter. The bracts of the cone scales are relatively broad and usually squarish (truncated) at their upper ends (Pl. XVII, *a*), or occasionally somewhat heart-shaped or notched at the top end with a small tooth-like point extending from the center. The pale yellowish-brown seeds (Pl. XVII, *b*, *c*) have shiny, faintly yellowish wings. The seed-leaves, which are very slender and pointed, are usually six in number, and about three-fourths of an inch long (Pl. XVII, *d*).

The wood of grand fir ranks fourth in weight among Rocky Mountain fir woods, a cubic foot of dry wood weighing about 22 pounds. It is soft, but firm enough to be useful as lumber, moderately wide-ringed and straight-grained. In color it varies from pale

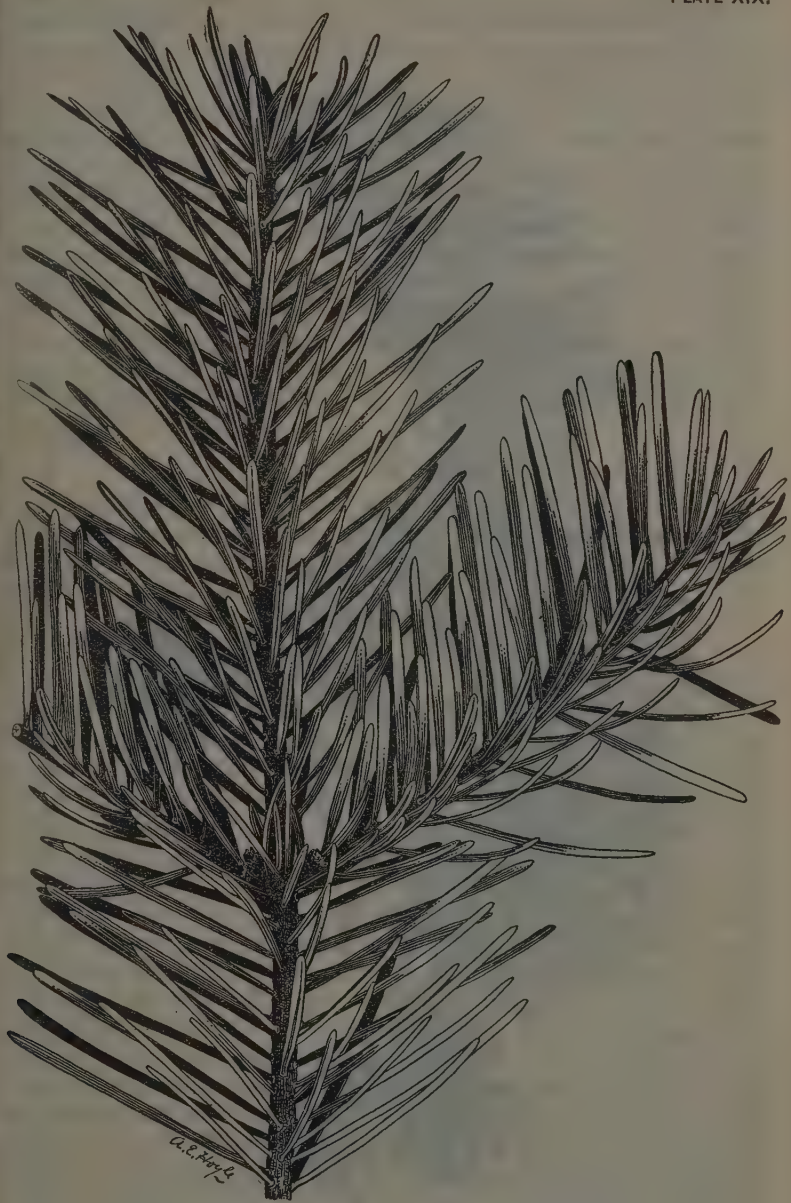
yellowish-brown to very light brown. The wood of this fir is little known in the Rocky Mountains and is only occasionally cut for lumber in the Pacific slope region, though its good quality entitles it to be better known and more widely used. The ease with which the wood can be worked, and other good physical qualities, render it the equal, if not the superior, of the softer fir woods now cut for lumber.

OCCURRENCE AND HABITS.

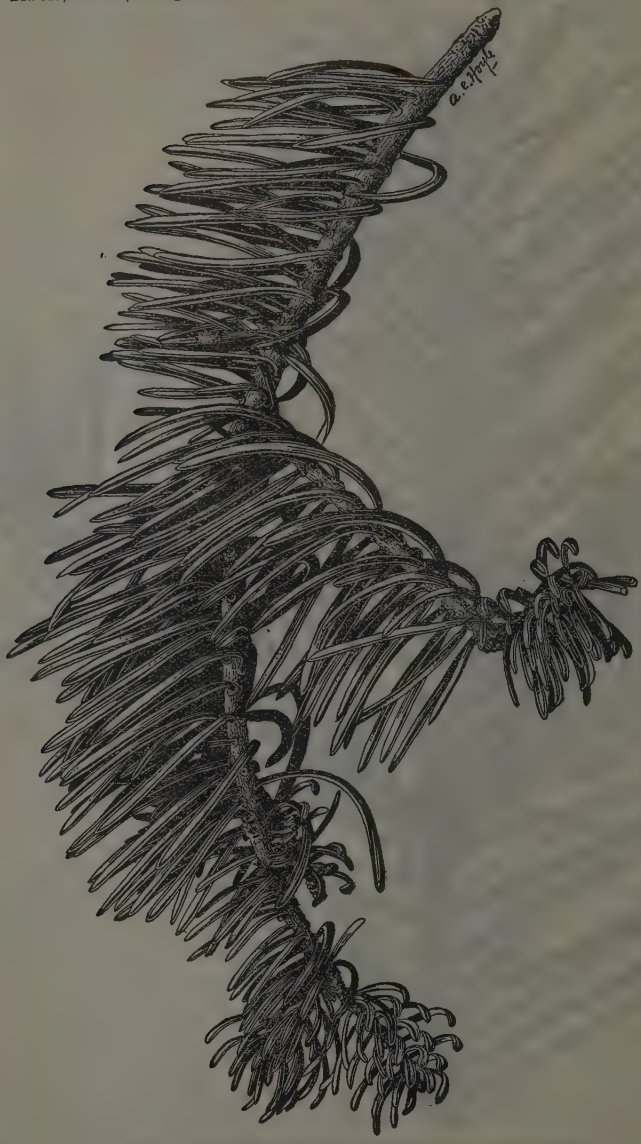
Grand fir is essentially a tree of moist situations. It grows most commonly on alluvial stream bottoms and adjacent higher ground, lower gentle mountain slopes, depressions, and gulches, at elevations between about 2,000 and 7,000 feet (Map No. 8). The best and most abundant growth occurs on stream bottoms at the lower levels, much smaller trees being found at high elevations. Its deep root system demands permeable, preferably moist, porous, well-drained soils. With favorable moisture and climatic conditions grand fir grows well on rather poor, thin soils, but better quality is necessary in soils deficient in moisture and subject to rapid evaporation.

Grand fir rarely occurs in pure stands, except of limited extent. Usually it is mixed with western white pine, lodgepole pine, western larch, Engelmann spruce, mountain red cedar, western yew, Douglas fir, black cottonwood, balm of Gilead, and sometimes with western yellow pine. The number of species and the percentages of the stand they represent in this association vary greatly in different localities within the general range of grand fir. It is always dominant when associated with mountain red cedar.

Grand fir is the least tolerant of shade, with one or two exceptions, of all of our fir trees, growing only moderately well under such conditions. It is much less able to live under the shade of other trees than the mountain red cedar, western hemlock, and western yew, but much more tolerant than Douglas fir, western white pine, western larch, and western yellow pine. Seedlings endure considerable shade for several years, but unless they are given full overhead light, such growths become dwarfed and die within a few years. With overhead light, the height growth of this fir is rapid, and under side shade the trunks are readily cleared of branches, forming the characteristic long, clean stems. Endurance of shade, however, varies in general with age, exposure, moisture of the soil and air, quality and quantity of available soil, altitude, and latitude. The largest trees are products of sufficient moisture, soil, heat, and full sunlight. Under these conditions it will also endure considerable shade. On poor, dry soils and in warm exposed places, shelter from cold winds and some shade are beneficial in reducing soil evaporation and transpiration;



ABIES CONCOLOR: LOWER-CROWN BRANCH OF YOUNG TREE.



ABIES CONCOLOR: LOWER-CROWN BRANCH OF OLD TREE.

therefore in regions with such conditions the tree confines itself mainly to cooler northern slopes and other protected sites.

Abies grandis is a fairly prolific seeder, trees in open stands fruiting most heavily. Seed is produced mainly at irregular intervals of about 2 or 3 years; whether or not this species has the habit of regular periodic seed production is, however, not fully determined. Trees grown in the open occasionally produce a few cones when they are about 20 years old, seed production increasing thereafter up to old age. The seed has a rather low rate of germination and only transient vitality. Under favorable conditions some seed germinates soon after it falls to the ground, and seedlings may become established before cold weather. Moderately humous, shaded soils are most favorable to germination, but with sufficient moisture and light, seeds sprout readily and seedlings thrive in either pure humus or mineral soils. Seedlings come up both in the open and in shady places.

LONGEVITY.

The extreme age limit of this fir is unknown. It is probable, however, only a moderately long-lived tree, possibly attaining an age of from 200 to 250 years. One tree, 34¾ inches in diameter, showed an age of 196 years.

WHITE FIR.

Abies concolor (Gord.) Parry.

COMMON NAME AND EARLY HISTORY.

Abies concolor is a massive tree fitly and widely called white fir because of the light ashy hue of its bark. A few other local common names applied to it, such as "silver fir," "white balsam," etc., also refer to this characteristic.

The white fir was first discovered in the southern Rocky Mountain region by a Russian collector of plants named Augustus Fendler,[1] who found it in 1847 near Santa Fe, N. Mex., while exploring there under the protection of United States troops stationed in that country during our war with Mexico. It was not discovered in our Pacific slope country, where its more extensive range lies, until 1851, when John Jeffrey collected specimens of the tree in northern California.[2] The first technical name applied to white fir, the one it now bears, was published in 1850, but without a botanical description, an omission which left this name legally unestablished until 1875. The earliest properly established technical name applied to white fir is "Picea concolor Gordon," which was published in 1858, and on which

[1] Asa Gray, in Am. Journal of Sci., xxix (ser. 3), 169; Canby Bot. Gaz., x, 285, 301.
[2] Sargent, Silva, XII, 124.

Abies concolor (Gord.) Parry is technically based. Botanists have generally maintained this name, although since its establishment some fifteen other specific and varietal names (now made synonyms of *A. concolor*) have been published. These names were created chiefly, however, either through confusion of the white fir with other North American firs, or through imperfect knowledge of the variable forms of the tree peculiar to different parts of its extensive range.[1]

One of the best marked varietal forms of white fir well known in cultivation is Abies concolor lowiana (Murr.) Lemmon. It has short pale green foliage and occurs in the California Sierras and in the Siskiyou Mountains of southern Oregon. European dendrologists have segregated five other cultivated varieties, chiefly by the color of their foliage, shape of the leaves, and habit of the crown or of its branches. The characters relied upon to distinguish these latter garden forms do not, however, appear to be sufficiently dependable to warrant maintaining the plants as distinct varieties.

DISTINGUISHING CHARACTERISTICS.

White fir grows to its largest size in the Pacific region, where it is frequently from 140 to 180 feet, and occasionally over 200 feet, high, with a diameter of from 40 to 60 inches, rare trees being from 5 to 6 feet through. In its Rocky Mountain range, however, white fir is a much smaller tree, at best being only from 80 to 100 feet in height, or rarely more, and from 20 to 30 inches in diameter. The massive trunks have conspicuously rough ash-gray bark, which is broken into great, deep, wide furrows and ridges. The bark is very hard and horny and from 4 to 6½ inches thick on the largest trunks (Pl. XXIV). Bark of the upper stems of large trees and on young trees is smooth and unbroken and grayish, with a slight brownish tinge. The trunks are straight and taper very gradually. The dense crown of heavily foliaged short branches is an irregular, round-topped cone, extending to the ground on trees in open stands, while in dense stands the crown covers only one-third or one-half of the stem. Young trees have beautifully symmetrical, sharp crowns extending down to the

[1] According to Elwes and Henry (Trees of Great Britain and Ireland, IV, 780, 1909), the California form of white fir was first introduced into England in 1851, while the Rocky Mountain form of this species was introduced there in about 1872. Trees raised from California seed are said to grow more thriftily in England than stock from Rocky Mountain seed. One tree in Oxfordshire attained a height of 71 feet and a diameter of about 2 feet in 28 years. The largest trees growing in England are from about 70 to 90 feet in height and from 20 to 40 inches in diameter. The German Government purchased considerable quantities of white fir seed, both of the Rocky Mountain and Pacific slope forms, in the early nineties for experimental forest planting in Germany, but the results of these trials are unknown to the writer at present. Doubtless the Rocky Mountain form has proved more adaptive to German conditions, judging from the excellent growth of Douglas fir from this region and the failure there of Douglas fir plants raised from Pacific slope seed. White fir from the Rockies and the Pacific slope grows thriftily in eastern United States but stock from the interior mountains is far better adapted to this region than the more western form, while for ornamental planting the Rocky Mountain trees are much handsomer in form and in bluish-tinged foliage.

ground, the lower limbs standing out horizontally and those above trending upward. Six to ten year old trees have not yet assumed this sharp-pointed form of crown, and all of their branches are commonly at right angles to the stems (Pl. XXIII, *d*). On old trees the lower-crown branches droop conspicuously, as do also those of the middle crown; while branches above this trend upward. In old age the extremely slow or practically arrested growth of the leader and the continued growth of the upper side branches forms a rounded top. Twigs of a season's growth are smooth, shiny, and yellowish-green, later becoming ashy or brownish-green. The scaly winter buds are from one-eighth to three-sixteenths of an inch in diameter and covered with resin.

The color of the foliage varies in different parts of the tree's range from a yellow-green (with distinct bluish cast when young) to pale yellow-green with whitish tinge. The newly-matured foliage of old trees is, however, often decidedly bluish for a season, but later becomes much paler. In general, trees of the southern Rockies are apt to have much bluer foliage than those grown farther north, while, as a rule, the foliage of Rocky Mountain trees is whiter or bluer than is the case with Pacific slope trees. The leaves are flat, plump, blunt, or pointed (usually not pointed on lower and middle-crown branches, but sometimes pointed on lower branches of old trees) and are crowded, apparently, on the upper sides of the twigs and branches (Pls. XX, XXI, and XXII). On the lower branches of young trees they are horizontally flat, straight, and stand out more or less distinctly from two sides of these branches by a twist at their bases (Pl. IX). Very commonly, however, the leaves of the lower branches of young trees, and nearly always of old trees, are curved upward and stand erect somewhat in two lines from the top side of the twigs (Pls. IX and XX). Leaves of the upper crown, especially on the topmost branches, are strongly curved or sickle-shaped and appear to grow from the upper sides of the branchlets (Pls. XXI and XXII). The leaves of upper branches and those on leaders are always sharp-pointed. Lower-branch leaves are usually from 1½ to 3 inches long, while those of the upper branches are commonly from about 1 to 1½ inches long. There is also great variation in the length, form, and thickness of the leaves of this fir in different parts of its wide range.[1] A cross-section of a leaf shows two resin ducts each one situated very near the corner of the section and on the lower side. Both surfaces

[1] The changes in form from straight, horizontally flattened leaves to vertically flattened ones, either straight or curved like a sickle blade, are curious and unexplained, except perhaps by the fact that the latter form may present less leaf surface to the direct rays of the sun, thus fitting the tree to better endure the hot, dry climate in which this form of foliage is most common. Some authors hold that white fir of the Rocky Mountains bears longer leaves, and more commonly pointed ones, than do trees of the Pacific forests. The writer has, however, seen white fir in the latter region with quite as long leaves, while blunt leaves are not infrequent on trees in the Rockies.

of the leaves bear lines of minute pores (stomata), which give a whitish or pale bluish tinge to the foliage.

The cones (Pl. XXIII) are mature early in September, when they may be either very pale olive-green with an ashen tinge, or clear chrome-yellow green, while sometimes they are purple. They vary in length from about 3¼ to 4¼ (sometimes nearly 5) inches. The bracts, attached to the back of the cone-scales (Pl. XXIII, *a*), are sometimes rather narrow and oblong, or occasionally broad and rounded, the free end having a small, wide-based point extending from its center. The seeds (Pl. XXIII, *b*) are a dingy yellow-brown with shiny, clear, rose-tinted wings. The seed-leaves are commonly 6 in number, or occasionally 7.

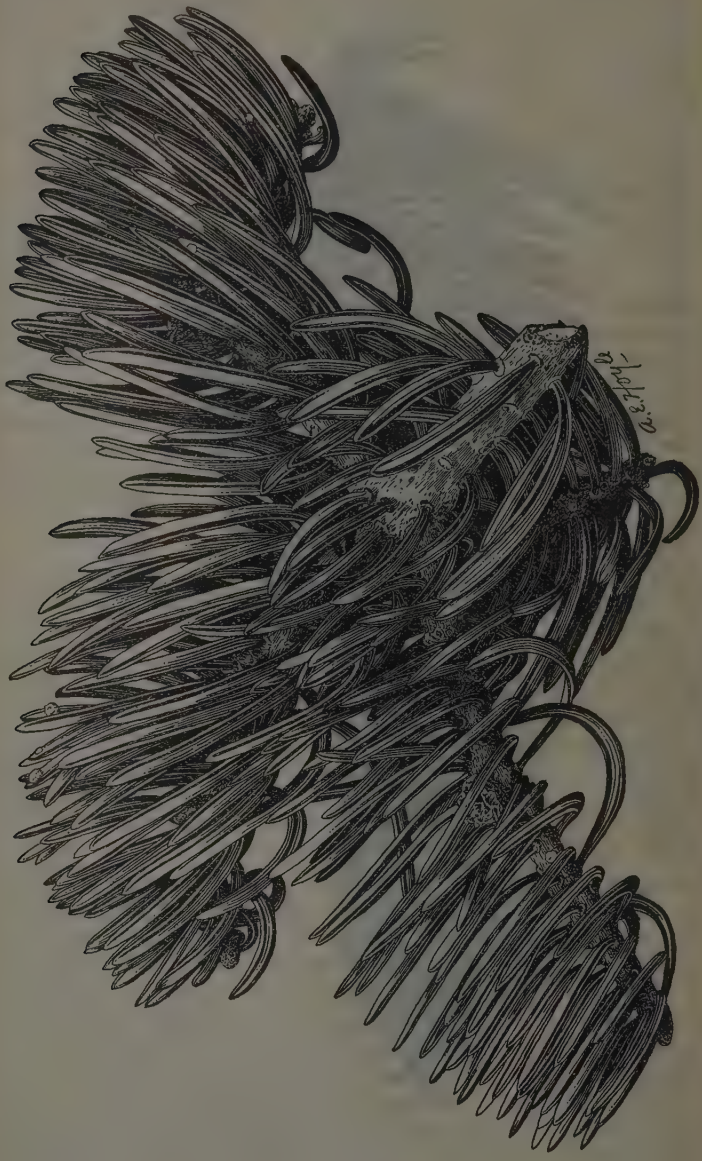
White fir wood varies in color from whitish to a pale indistinct brown, being soft, rather wide-ringed, and straight-grained. In weight it ranks third among other Rocky Mountain firs, a cubic foot of dry wood weighing about 22½ pounds. It works easily, and is strong and hard enough to be useful for saw timber, for which it is cut to some extent. Many large trees are, however, affected with "punk-rot" or are wind-shaken, defects which render much of the old stands useless for commercial purposes.

OCCURRENCE AND HABITS.

White fir is for the most part a tree of moderate altitudes, occurring in general at elevations between 6,000 and about 11,000 feet, but more frequently at altitudes between 7,000 and 9,000 feet. It usually grows on north slopes, and is especially abundant on benches and the sides of moist canyons of these aspects (Map No. 9). White fir is less particular as regards aspect in the North than in the South. It thrives in almost all fairly moist, well-drained soils, except heavy clays. The best growth, however, occurs in fairly deep, rich, moist gravelly or sandy loam soils. Frequently, nevertheless, it occurs on dry, nearly pure, coarse, disintegrated granite, and even among bowlders, but it is of much smaller size in such situations. White fir requires less atmospheric and soil moisture than any of our other firs, yet its best growth is always in cool, moist situations.

Abies concolor never forms pure stands of mature trees over large areas, although it occurs frequently in nearly pure growths of limited extent. Douglas fir is very commonly associated with white fir, and alpine fir, Engelmann spruce, and aspen are found with it more or less. Occasionally it occurs with western yellow pine and limber pine. The frequent dominant stands of young white fir, which occur mingled with Engelmann spruce or Douglas fir, usually give way in numbers to the latter species when the pole stage is reached, so that the white fir later constitutes a much smaller percentage of the maturer stand than it did at the beginning.

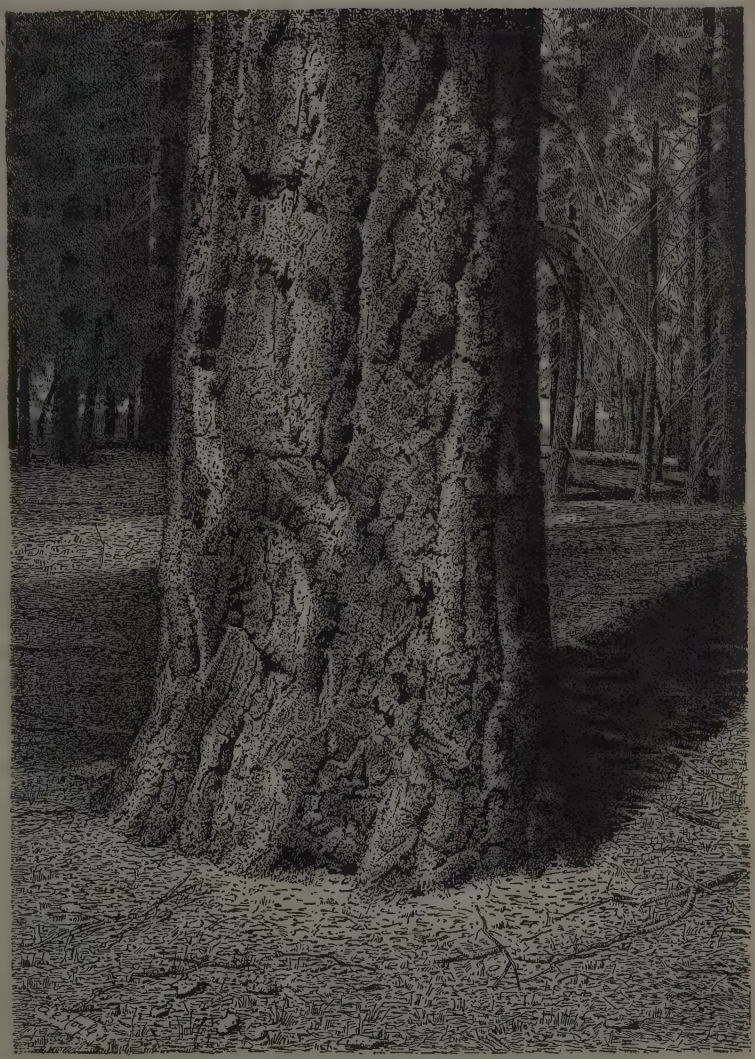
ABIES CONCOLOR: MIDDLE-CROWN BRANCH.



ABIES CONCOLOR: UPPER-CROWN BRANCH.

ABIES CONCOLOR: CLUSTER OF RIPE CONES; SCALES AND SEEDS NEARLY READY TO FALL FROM CENTRAL AXES.

a, Lower side of cone scales showing their bracts; *b*, upper side of cone scale with its winged seeds (as they are borne) and lower side of detached seed; *c*, seedlings about two years old; *d*, young tree seven years old (about one-half natural size).



ABIES CONCOLOR: TYPICAL THICK BARK OF TRUNK.

White fir is very tolerant of shade throughout its life, but it endures more shade from the seedling to the pole stage than at any other period. Such growths survive long suppression under heavy shade, but with slow progress, and recover readily when overhead light is admitted. White fir appears to be most tolerant of shade in moist soil, where usually it is able to endure more than any associated species except Engelmann spruce and alpine fir. Owing to its great tolerance, white fir has a closely branched crown, and the trunks lose their branches rather slowly.

White fir is a fairly prolific seeder, producing large crops of cones periodically. Good seed years occur only at irregular intervals of from two to four years, but some seed is produced nearly every year. As a rule, seed production begins mostly at a rather advanced age, but pole-size trees in dense stands may bear seed when their leaders reach full light. Seed bearing continues for many years, but it is more abundant during the period of rapid height growth (between the ages of 50 and 100 years) than at maturity. The seed has only a moderately high rate of germination (often under 40 per cent) and transient vitality. Reproduction is usually abundant, large dense groups of seedlings often resulting from a single tree's heavy seed crop.

The character of the seed bed is apparently of little importance, for seed germinates on moist, heavy litter and humus as well as in mineral soil. However, fairly abundant soil moisture is essential during the first few months following germination in order that the seedlings may become established. Indifference to the kind of seed bed renders this tree more than ordinarily agressive, reproduction occurring over denuded lands adjacent to seed trees as well as immediately under their own shade.

Large quantities of seed of this fir are eaten by squirrels[1] and probably also by other rodents which doubtless avail themselves of

[1] The remarkable sagacity of pine squirrels is shown by an incident observed by the writer in connection with their "cutting" of white fir cones in the Manzano National Forest, N. Mex. Part of the cones "cut" from a tree had necessarily fallen directly into a shallow pool of spring water beneath the tree, and it is equally certain that part of them fell on the border of the pool. The latter supply of cones had, however, evidently been dragged to the abrupt edge of the pool and pushed into the water. Altogether a bushel or more of cones were thus cached in the water. Evidence that the squirrels had deposited part of the cones in the water appeared in the fact that cones were especially numerous in the water at the edge of the pool. None were to be found anywhere on the ground about the pool. While the squirrels were not actually seen at work, the position of the tree with reference to the pool was such that only a part of the cones "cut down" could have fallen directly into the water, while the remainder clearly must have reached the ground. The writer was informed by a settler's lad who frequently passed the pool that he had seen the squirrels dragging cones to the water's edge. The effect of placing ripe fir cones in water is to prevent them from breaking up and liberating their seeds, which occurs when the cones are left on the ground exposed to the air. While it is believable that the placing of these cones in the water may have been in accordance with the instinct of squirrels and many other rodents to cache their winter supply of food, it seems quite unbelievable that the squirrels could know and profit by the fact that immersing fir cones in water temporarily preserves them intact.

the abundant supply of cones the squirrels "cut down." During light or poor seed years this consumption may in some localities well include practically the entire crop, but in seasons of heavy seed production, the loss from rodents must still allow abundant reproduction.

LONGEVITY.

In general white fir grows rapidly in height and diameter for the first 50 to 100 years, after which it grows slowly up to about 350 years, which is believed to be near its maximum age. The age limit of white fir in the Rocky Mountain region is not fully known at present, but very probably the largest trees are not over 250 or 275 years old.

SHASTA RED FIR.

Abies magnifica shastensis Lemmon.

COMMON NAME AND EARLY HISTORY.

The Shasta red fir has only a very limited range in the Rocky Mountain region (Map No. 10; western edge of Nevada), its principal range lying in the Pacific slope region.

From the forester's point of view Abies magnifica and its variety, A. magnifica shastensis, which is distinguished from the former by its shorter and thicker cones and by the exserted bract of its cone scales (Pl. XXV, *a*), are practically one tree. Indeed, without seeing the mature cones of the species and its variety, it is impossible to distinguish one tree from the other. Their silvical habits and habitat are essentially the same.

The common name, Shasta red fir, derived partly from the technical name, is probably not used by woodsmen and other laymen who generally call the species and variety "red fir." The name Shasta red fir refers appropriately to the deep red-brown bark which both the species and its variety invariably have throughout their range, and to the historical fact that the tree was originally found on Mount Shasta, Cal.

Abies magnifica was first discovered in 1845 by Col. Frémont on his expedition to California, the first authentic description of it appearing in 1863. The Shasta red fir was found first on Mount Shasta, Cal., in 1852 by the intrepid Scotch explorer John Jeffrey. The earliest technical name given to this form is probably "Abies nobilis rubusta" of Carrière, published in 1867; but it is impossible to be sure now that Carrière's accompanying description applies to the Shasta fir, which in 1890 was properly distinguished for the first time as "Abies magnifica var. shastensis" by Dr. J. G. Lemmon.

This author later believed it to be a distinct species, and in 1897 published the name "Abies shastensis." A long and careful field study of this tree has convinced the writer, however, that it is only a varietal form of Abies magnifica.

DISTINGUISHING CHARACTERISTICS.

Abies magnifica is a tree of stately dimensions, ranging from 125 to 175 feet in height, or very exceptionally 200 feet or more, and from 30 to 50 inches in diameter; trees from 60 to 80 inches in diameter are rather rare. Much larger trees are said to have been found, but the writer has never seen them. Abies magnifica shastensis occurs only at high elevations where conditions for growth are much less favorable than within the main vertical range of the species, so that it rarely exceeds 125 feet in height and 3 feet in diameter. In close stands at lower elevations the trunks of large trees are straight and slightly tapering. Smaller trees on high exposed slopes are often conspicuously and permanently bent down the slope at their base, as a result of heavy snows which yearly force the seedlings to the ground. Their later struggle to regain an upright position never wholly rids the trees of this basal bend in the trunk, which remains a mark of early vicissitudes.

The bark of young Shasta red fir trees is smooth and conspicuously chalky white, as it is also on the upper stem and branches of old trees, while on the lower trunks of older trees it is rough with deep furrows and narrow, rounded ridges. It varies in thickness from 2 to 3 inches according to the size of the tree. The main vertical ridges of the bark are irregularly divided by diagonal furrows, which give a peculiar zigzag appearance to the bark. Externally the rough bark of old trunks is a deep purplish-brown and a bright purple-brown within. No other fir tree in this region has bark similar in any particular to this.

The crown of old forest grown trees is a short, very narrow, round-topped cone, sometimes almost cylindrical. The short branches droop except at the top of the crown, where they trend upward. The crown is noticeably open, due to the fact that the circles or whorls of branches grow from the trunk at rather wide and regular intervals. Only in the densest stands are medium-size trees clear of branches for half or more of their length. In the high, fairly dense Pacific Slope forests many trees bear straggling branches nearly to the ground. At high elevations, too, the brittle tops are often broken off by wind, when the lost member is replaced by the upward growth of one or two side branches, which soon assume the form and place of leaders. Broken and repaired crowns of this type are familiar sights on wind-swept slopes inhabited by this fir. Young

trees (30 to 50 years old and as many feet high) have narrow, cylindrical, sharp-pointed crowns, extending down to the ground. All of the regular groups of branches, except the topmost, sweep down and upward at their ends in graceful curves, presenting a form which is unsurpassed in beauty and symmetry by any of our other conifers.

The sharp-pointed winter buds are light chocolate-brown and about one-fourth of an inch long. Unlike the winter buds of other firs of this region, those of the Shasta fir are not resinous.

The dense foliage is dark blue-green, with a whitish tinge; new leaves, produced each season, are at first a much lighter green and more conspicuously whitened than when older. The leaves are four-angled, with nearly equal sides, the angle on the upper sides of the leaves being rounded. Leaves of the lower branches (Pl. XXV, *b*) are flatter than those on other parts of the crown (Pl. XXV, *a*). Those on the lower side of the branches are so bent that they appear to grow from the top side of the branch, and mainly in two dense upright lines. All of the leaves are, however, more or less curved. The leaves of lower branches are from three-fourths of an inch to about 1¼ inches long, blunt or rounded at the end, and wider there than at the base. Leaves of the upper-crown branches (Pl. XXV, *a*) are more strongly four-sided and stouter than those of lower branches and are conspicuously curved and densely crowded toward and on the top of the branches. They are from five-eighths of an inch to about 1⅜ inches long and more or less distinctly pointed; leaves of the leader are also somewhat sharply pointed and incurved to the stem.

The cones (Pl. XXV, *a*) are mature by the middle or end of August, and during September they break up and liberate the seeds (Pl. XXV, *c*). At maturity they are deep purple in color and often tinged with brown. They vary in length from about 4½ to 5½ inches by about 2½ to 3 inches in diameter and in form from cylindrical to a long egg shape. The bracts, attached to the backs of the cone scales, are always broad at the end and in some cases scarcely or only slightly extended beyond the ends of the cone scales (Pl. XXV, *a*), while in others the bracts may be conspicuously extended (Pl. XXV, *d*).[1] The large-winged seeds (Pl. XXV, *c*) are dark brown, with shiny, purplish or rose-colored wings. The seed-leaves vary from 9 to 13, but are usually 12, and are about five-eighths of an inch long and bluntly pointed.

[1] Shasta red fir trees have been found bearing some cones with plainly exserted bracts and others with bracts entirely hidden. The hidden and exserted bracts do not differ essentially in form. In 1899 the writer found a group of trees at "Alta Meadows" (Sequoia National Park, Cal.), on some of which all of the cones bore exserted bracts, while on other trees the cones bore only hidden bracts. There is a sharp distinction between the form of the bract produced by Abies magnifica and its variety shastensis, bracts of the latter being broadly rounded at the end (Pl. XXV, *d*) and bracts of the species being narrowly lance pointed (Pl. XXV, *e*). No forms of bracts strictly intermediate between these extreme types have as yet been discovered.

ABIES MAGNIFICA SHASTENSIS.

a, Upper-crown branch and ripe cone; *b*, lower-crown branch; *c*, upper side of cone scale with one of its winged seeds and lower side detached seed; *d*, lower side of cone scales showing large form of protruding bracts; *e*, lower side of cone scale showing smaller and shorter bract of *Abies magnifica*.

The wood of Shasta red fir is the heaviest of all the firs in this region, a cubic foot of dry wood weighing about 29 pounds. It is yellowish-brown in color with a reddish tinge, straight-grained, usually narrow-ringed, and of a soft but firm texture. The wood of old trees is rather brittle. In an unprotected state the seasoned wood is considerably more durable than that of any other native fir. The commercial value of the better grades of this wood is yet to be determined. When other timber of lower elevations becomes scarcer the firmness and good working qualities of Shasta red fir wood are likely to render it useful for a number of the purposes to which pine is put. At present the tree is not cut for commercial purposes.

OCCURRENCE AND HABITS.

Shasta red fir is essentially a tree of high mountain habitat, sometimes well up to timber line. It occurs generally at elevations between 5,500 and about 10,000 feet, the higher elevation being reached in our southern Sierras. Within the Rocky Mountain region it occurs chiefly at elevations from about 6,000 to 8,000 feet, the main growth lying between 6,800 and 7,500 feet (Map No. 10).[1] It grows both on protected, gentle mountain slopes about meadows, in cool, sheltered ravines, gulches, and on high rolling mountain plateaus, as well as on steep, exposed, wind-swept mountain sides near high divides and crests. Shasta red fir prefers north and east exposures, where it is confined mostly to the available moist, cool sites. It is much less frequent on drier and warmer southern exposures in the former locations. The tree grows most abundantly and to the largest size, in moist, porous, sandy or gravelly loam soils; but it is found also in very rocky, poor situations with little available soil. Poverty of soil and moisture in such places, however, produces small or stunted trees. Under favorable conditions for growth Shasta red fir forms large pure stands and also nearly pure stands, the latter being interspersed more or less with scattered growths of lodgepole pine, western white pine, and white fir.

Shasta red fir is only moderately tolerant of shade at any period of its life, full enjoyment of sunlight being required for the best development. It is much less tolerant of shade than white fir, incense cedar, and Douglas fir, but very similar to noble fir in its requirement of light. Rarely to any extent does Shasta red fir grow in intermediate or subordinate positions, but nearly always in stands

[1] The exact range of Shasta red fir has not been fully worked out. Following its first detection on Mount Shasta, California, it was found on the coast and cross ranges of northern California, and also on the Cascade Mountains of Oregon. Later it was observed by the writer on the divides of Kaweah River watersheds and elsewhere far south of Mount Shasta, in the southern Sierras, while still later it was found to be abundant on Washoe Mountain in northwestern Nevada.

of equal age, which favor overhead light to all of the trees. It en dures but little side shade, as is shown by the long, clean trunks produces in close stands and commonly also even in rather ope stands. Ability to endure shade, however, appears to vary with th nature of the soil, available moisture, and climatic conditions, tree always showing relatively greater tolerance of shade under the be conditions for growth.

Shasta red fir seeds plentifully, good crops of cones being pro duced about every two or three years. Seed production is usuall greatest in the more open stands of moderately old trees. The see has a fairly high rate of germination, but under ordinary condition of storage its vitality is retained for only a few months. Germina tion occurs abundantly on moist mineral soil in the open or unde light shade, being much less frequent or wanting on dry, thick duff Seedlings grow rapidly in cool, moist, sandy soil, soon restocking high slopes and openings cleared by fire or storm.

LONGEVITY.

Shasta red fir appears to be rather long lived. Trees from 20 to 36 inches in diameter are from 225 to 370 years old. Very large trees, not yet studied chiefly because the timber is not now cut for mill ing, would certainly show much greater ages. There are evident differences, not yet determined, in the longevity of trees growing on high, exposed slopes and those at lower levels in more protected places, trees of higher elevations naturally being considerably older than those of the same diameter growing at lower levels.

KEY TO GENERA.

Leaves four sided; cones hanging down or curved downward, the cone scales firmly attached and not falling away when the cones are ripe_ *Picea.*

Leaves flat, grooved on the upper side; cones upright, the cone scales easily detachable and falling away from a persistent spikelike central stem when the cones are ripe_____ *Abies.*

KEY TO PICEA.

Twigs smooth:

Leaves very keenly pointed and stiff; cones mostly 3 to 4 inches long_____ *Picea parryana.*

Leaves only moderately sharp-pointed; cones mostly 1½ to 2½ inches long_____ *Picea canadensis.*

Twigs minutely hairy:

Cones firmly attached to the twigs and persistent for a number of years_____ *Picea mariana.*

Cones lightly attached to the twigs and soon falling from the trees_____ *Picea engelmanni.*

KEY TO ABIES.

Leaves of lowest branches arranged in two ranks (on two sides of the twigs) and mostly notched at the end ..... *Abies grandis.*
Leaves of lower branches more or less densely crowded on the upper sides of the twigs and with no notch at the end:
Bark of the trunk soft and corky ..... *Abies arizonica.*
Bark of the trunk hard and tough:
(1) Irregularly and shallowly seamed ..... *Abies lasiocarpa.*
(2) More or less regularly and deeply furrowed and ridged:
(*a*) Externally dark reddish-brown ..... *A. magnifica shastensis.*
(*b*) Externally ashy-gray ..... *Abies concolor.*
Bark of the trunk scaly, the small scales easily detached .. *Abies balsamea.*

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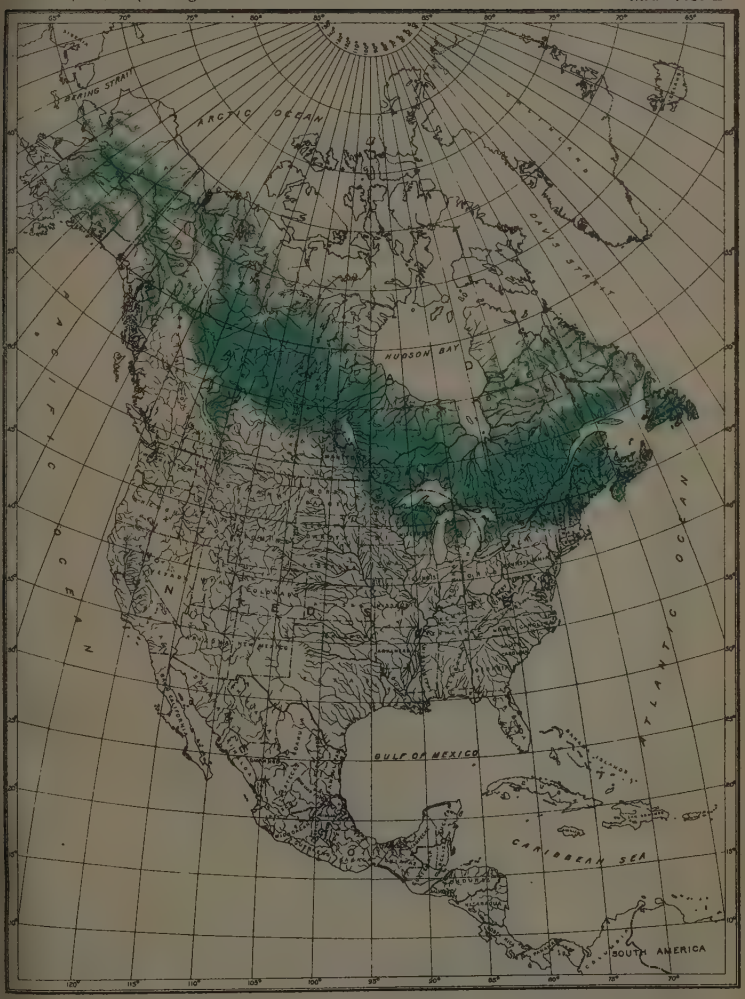

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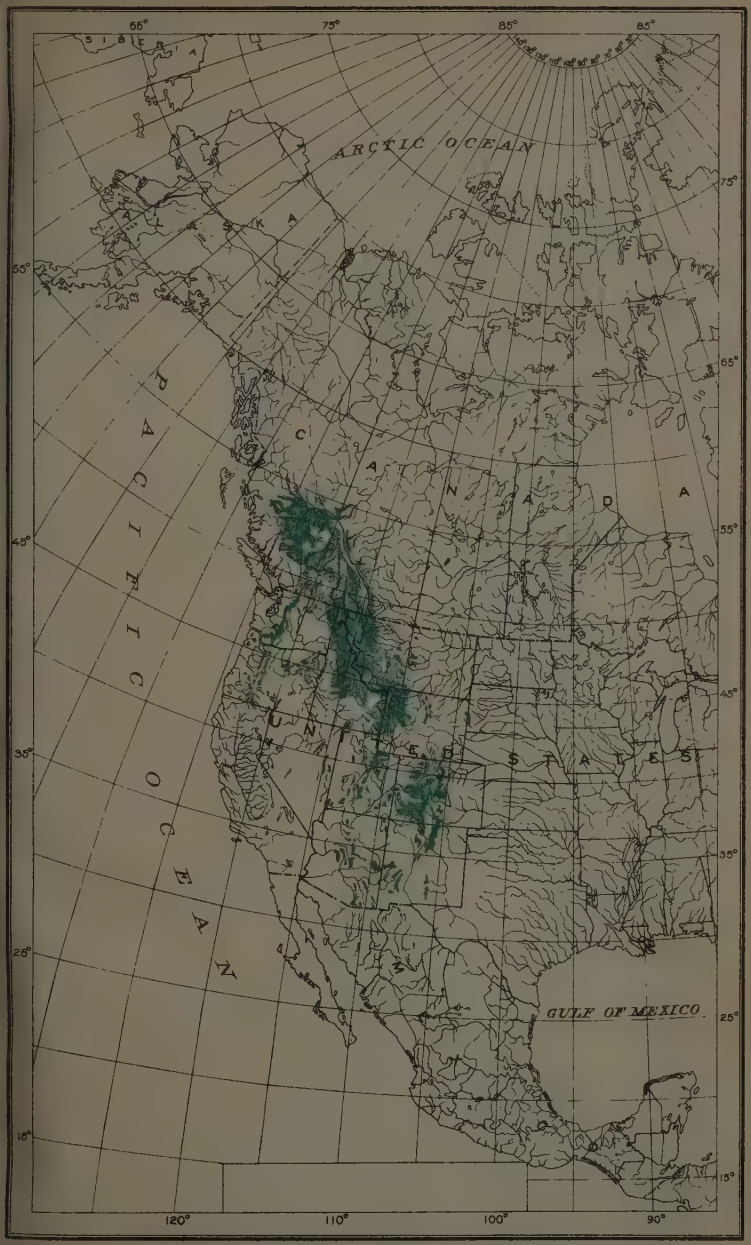

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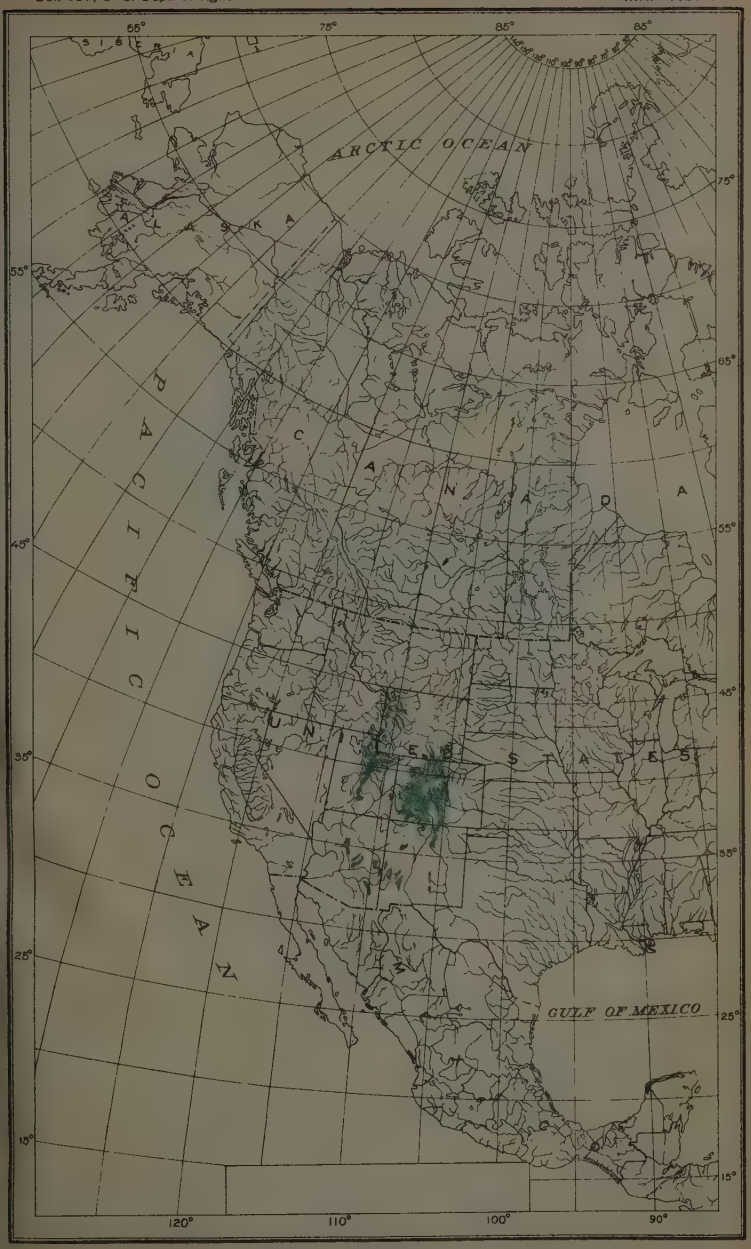

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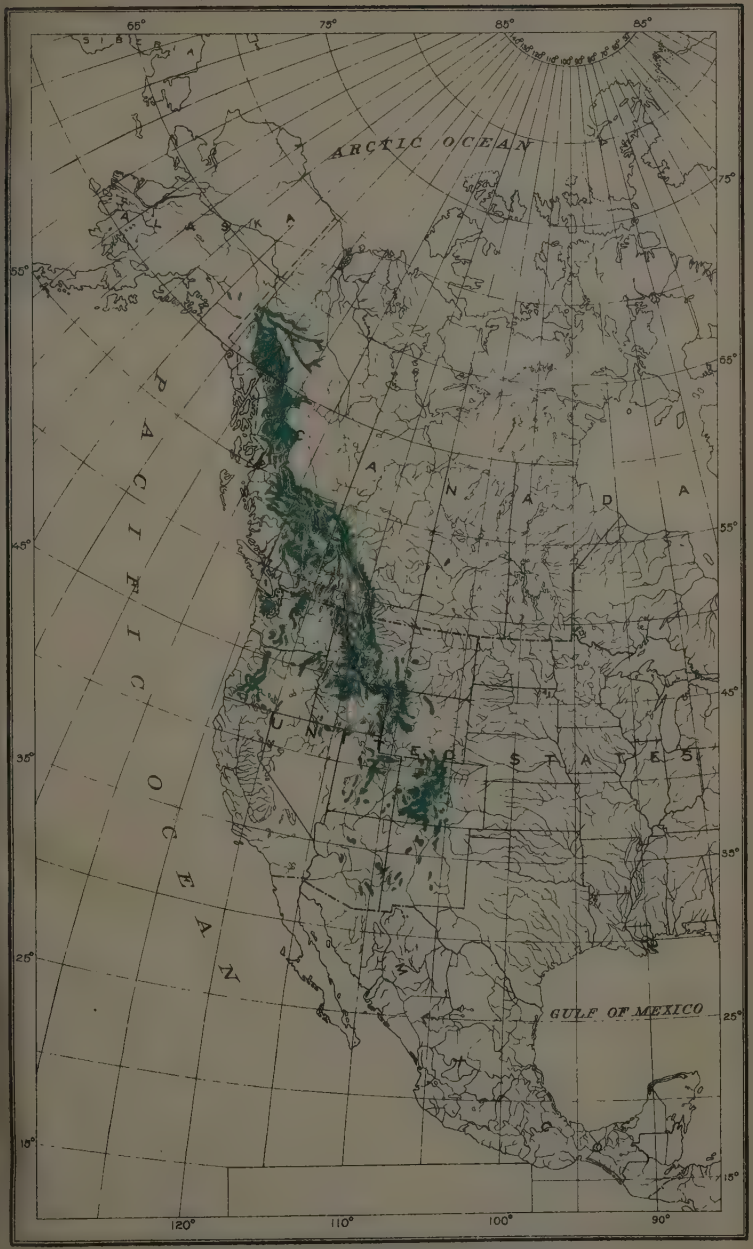

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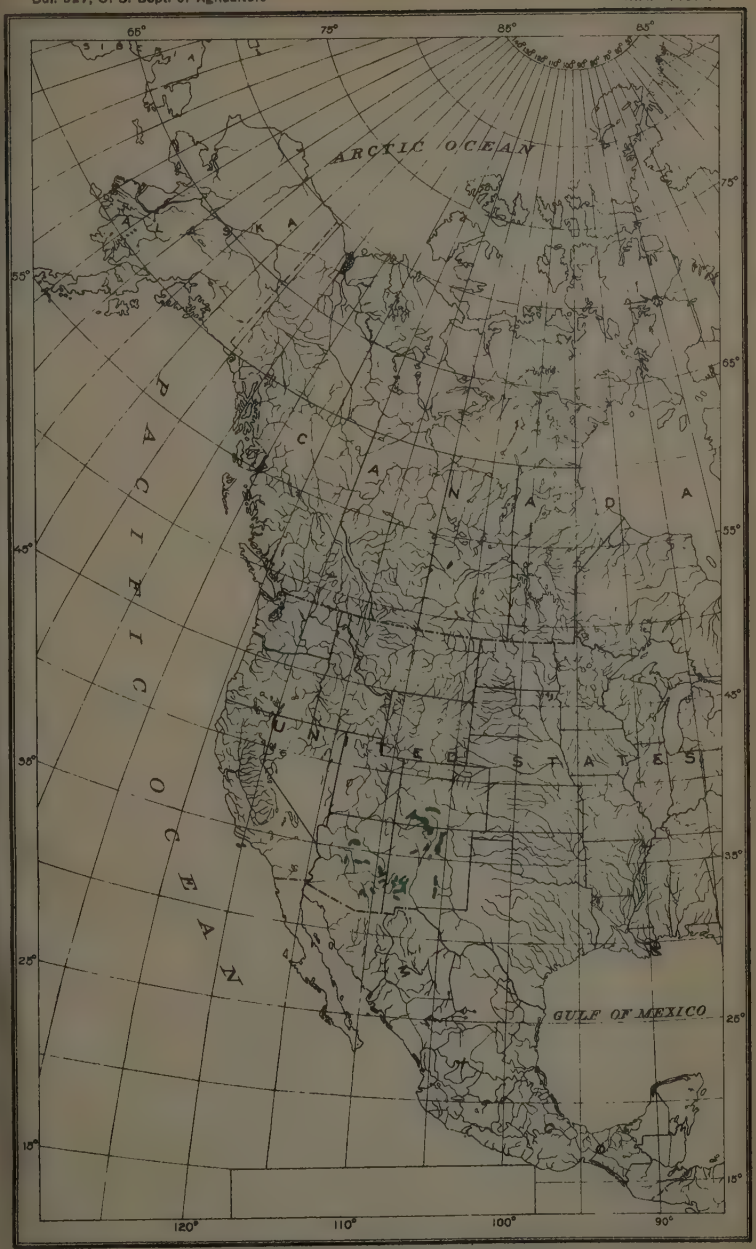

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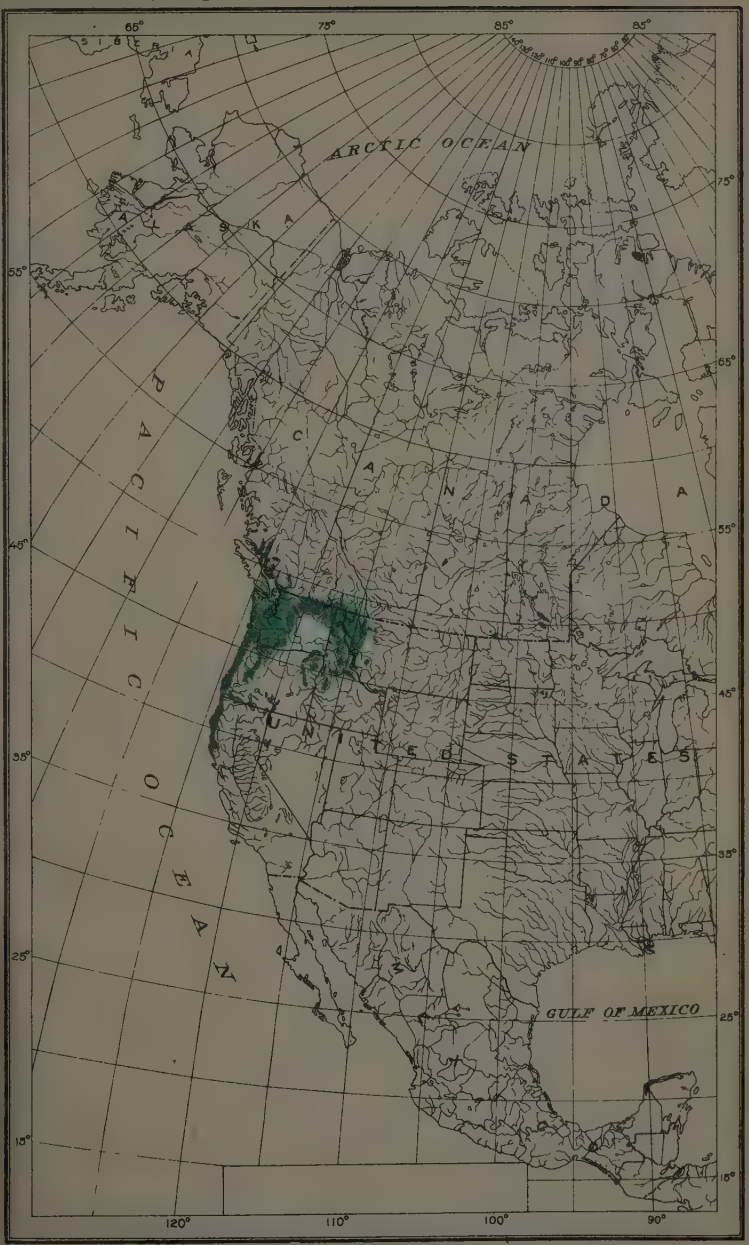

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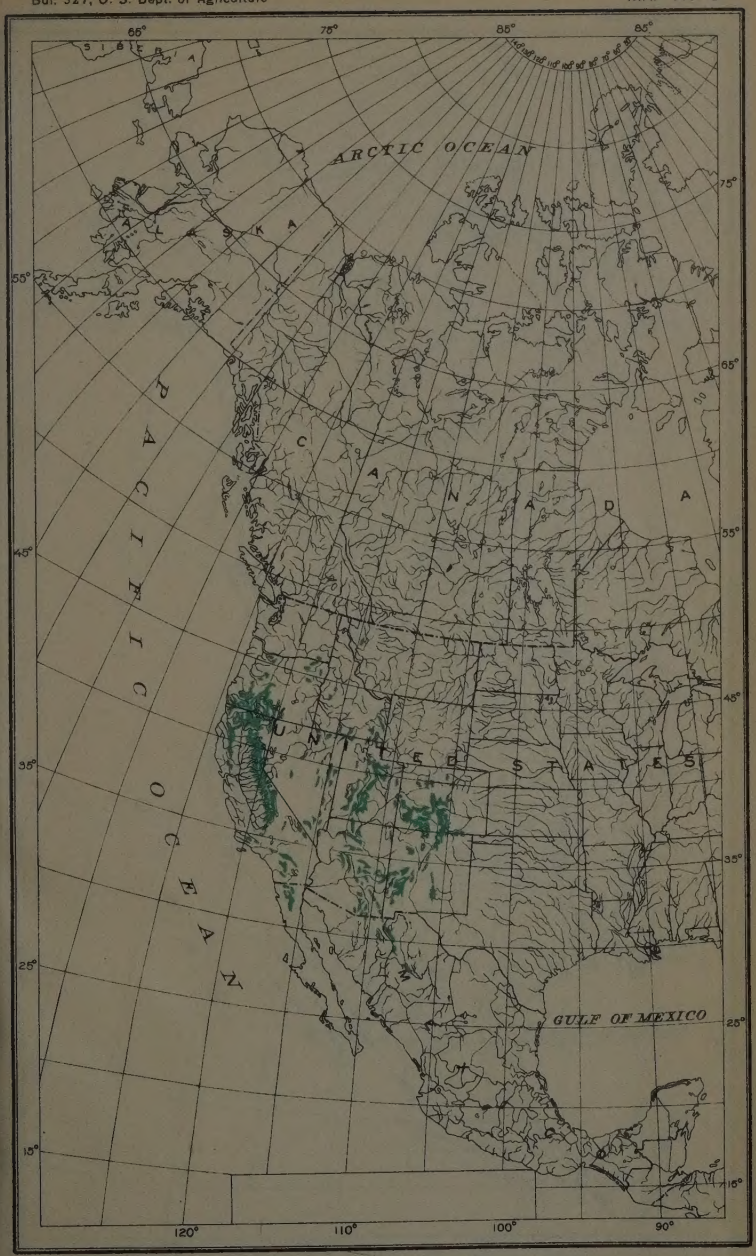

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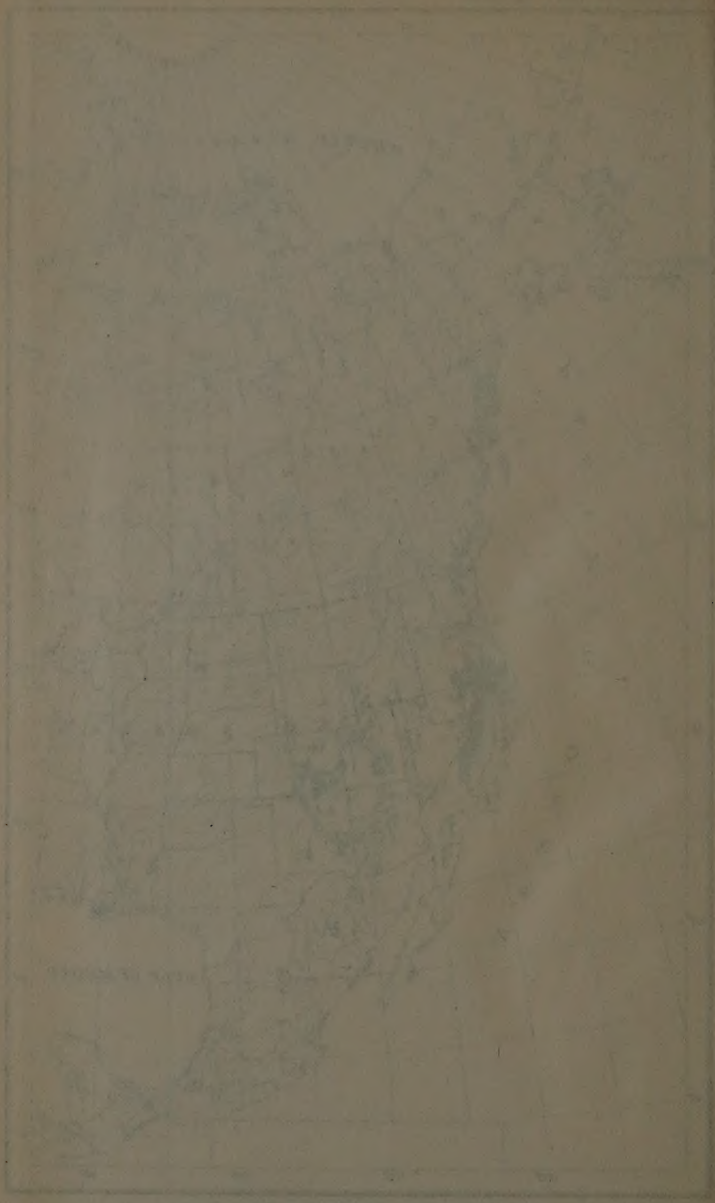

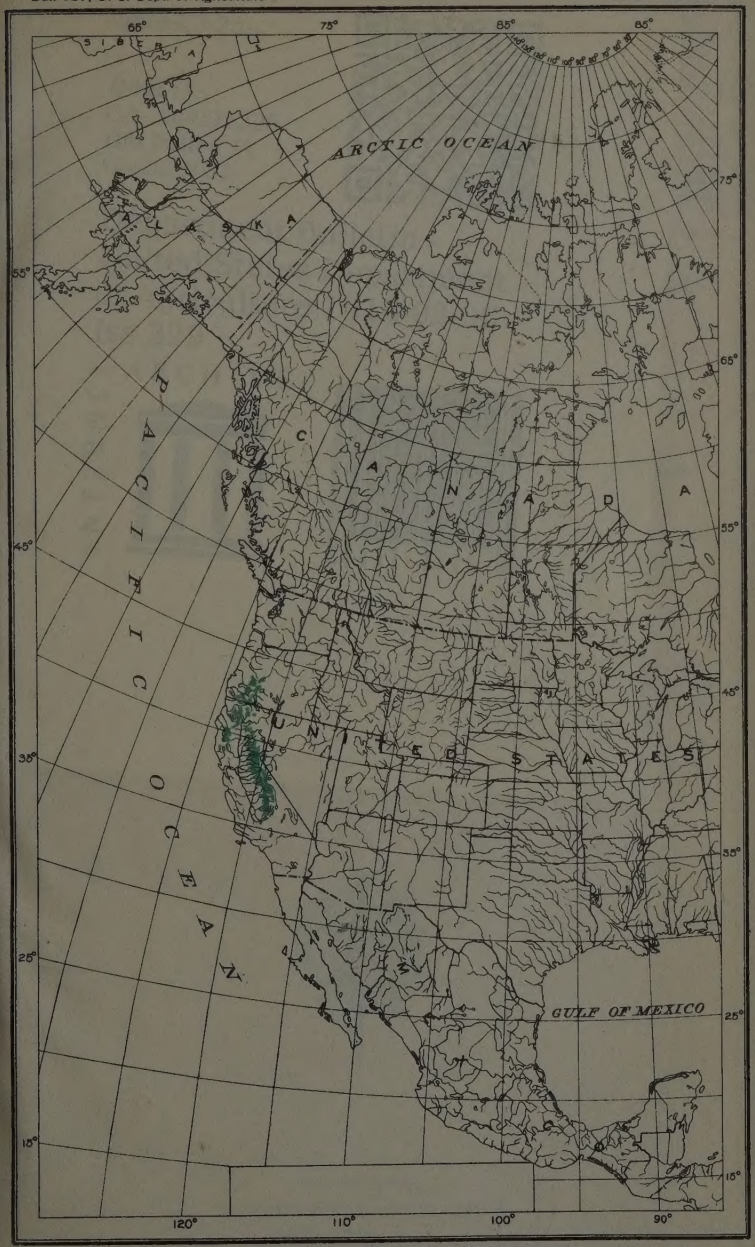

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